The Welding Journal

THE JOURNAL OF THE AMERICAN WELDING SOCIETY, PUBLISHED FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING

VOLUME 16 MARCH 1937 NUMBER 3

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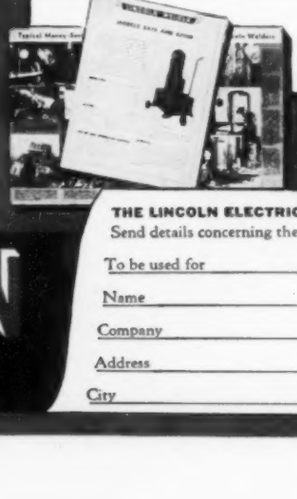

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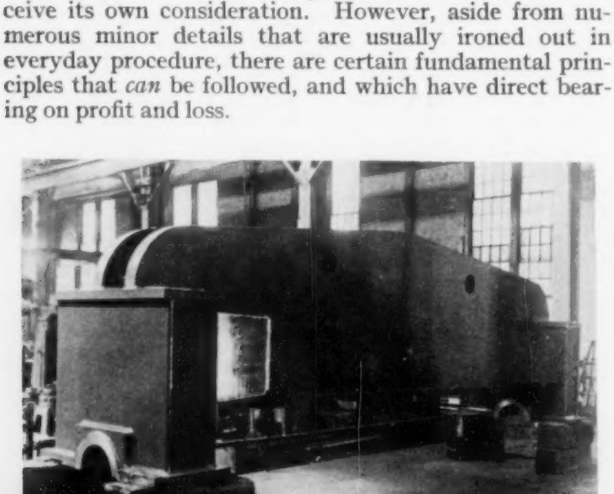
Welded Steel in Heavy Machinery*

By HAROLD VERSON†

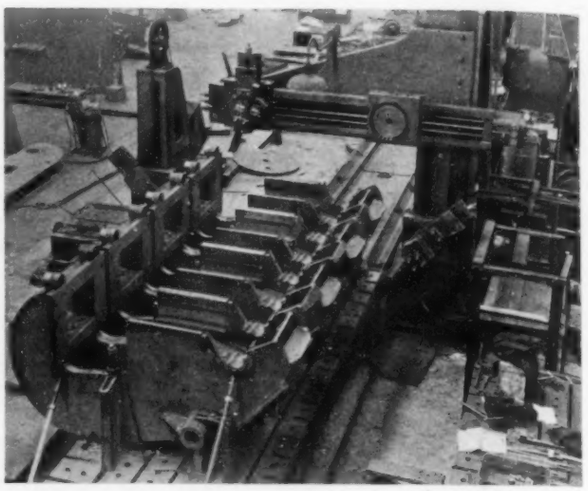
THE application of electric welding to the manufacture of heavy machinery is a process so natural, that like all other simple transitions, it is apt to run away from us. This particular field offers so many possibilities, and can be approached from so many angles that particular attention must be paid to every phase of design and construction. It is not only a matter of designing a structure to perform a certain job, but also of designing that structure so that it can be constructed in the most economical way.

We are all by this time sufficiently cooled off from the mad scramble to weld everything, to really attack each individual problem, not only as to the best way to design it as a welded structure, but to consider whether an entirely welded structure *is* the best design. We have finally come to the refinement processes which will not only improve our welded products, but which take into account several important factors which we have overlooked or ignored. It is no longer a question of whether to weld or to cast, but whether, by designing in a certain way or by combining the two will we get a more rigid, and better appearing product, at a lower cost.

The designer should, and can, decide very early in the design, the definite line of procedure. A practical knowledge of the materials with which we are working, plus a general idea of cost is all that is necessary. However, to set down a definite line of procedure, especially in heavy machine tool welding, would be foolish, because each individual shape and structure presents its own problems which must be handled in such a way as to compensate for this individuality. The size, shape and quantity, all have a direct bearing on cost, and each must receive its own consideration. However, aside from numerous minor details that are usually ironed out in everyday procedure, there are certain fundamental principles that *can* be followed, and which have direct bearing on profit and loss.



A Crown Weighing Thirty Tons. Completely Fabricated and Constructed in Two Weeks Time



Housings of Four Open Back Inclinable Presses. Notice the Steel Casting Bearing Inserts and the Advantage of Running Several Housings Through the Shop at the Same Time

To begin with, a primary factor in heavy welding is that of limited handling facilities in the average shop. There are not so many shops in the entire country that can boast that they need not consider this an important item in their design. By handling facilities, I not only mean lifting capacity, but more important, the machining possibilities. If a given welded member is to be built completely in a shop of limited capacities, both in handling and machining, then it should be so designed that a minimum of time will be lost in either department. The shop should not be forced to be faced with a periodic headache trying to handle and machine a welded structure, which is entirely lacking in proper machining possibilities. A given member can be designed in two different ways and effect at least a 50% saving in one of them in handling, welding and machining time.

To do this, the completed structure must first be considered as composed of several units, each to be treated as an individual structure. By doing this, not only is the design as a whole bettered, since more attention is paid to detail, but costs are directly reduced in almost every department along the line. First, it is possible to use smaller pieces of steel, and by so doing, provide an outlet for steel which would otherwise be unusable. Each small member is far easier to line up individually and can in all probability be welded without the necessity of using a crane for positioning. This procedure reduces handling to a minimum, since if all welding was left to be done until the entire structure was tacked together, it may be necessary to position it in sixteen different ways in order to weld it properly. This is a dangerous and costly procedure. Dangerous, because of its great size and costly because at least two men and a crane are required to do what one man and a jib crane could probably do.

More often than not, each individual member can be rough machined wherever necessary, before it is tacked

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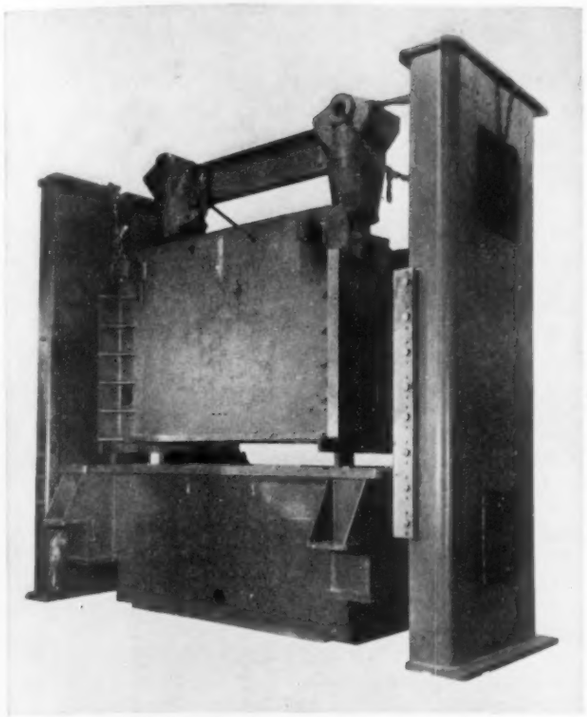
* Presented at Jan. 21, 1937 meeting of Milwaukee Section, AMERICAN WELDING SOCIETY.

† Chief Engineer, The Allsteel Press Company.



A Double Crank Press During Process of Assembly. Notice How the Use of Bent Plate Adds Beauty to the Appearance of the Uprights

to the other members, and thereby save at least one roughing cut on a larger, more expensive machine tool. Then again, there may be numerous holes or cutouts that can be provided in the sections, and so save expensive set-ups later on. Another factor to consider, and in reality one of the most important in welding, is that a structure composed of several rigid individual members is less liable to warp in the final process. All that may be necessary would be to provide small triangles and support plates at necessary points to keep overhanging plates from pulling over.

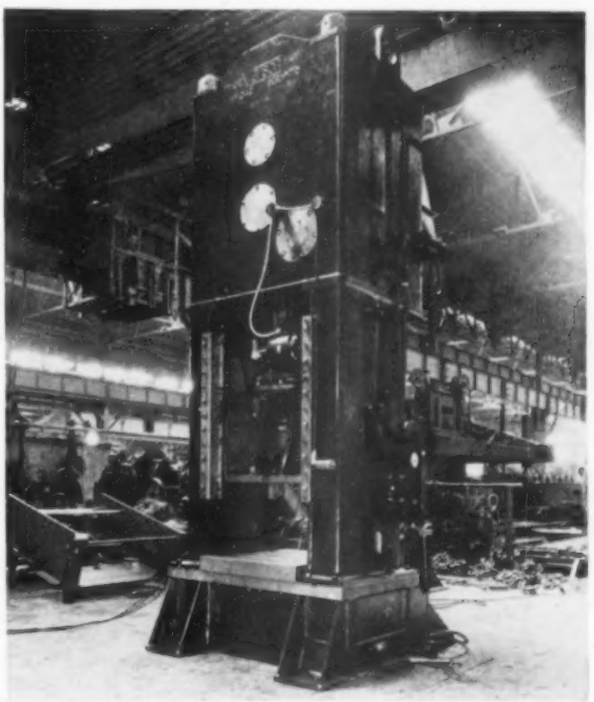
Another principle to consider in heavy machinery is the constant problem of light plates and more welding, against heavy plates and less welding. Is it better to effect a structure of several light plates properly located, or have two or three heavier plates, and consequently less welding? Each has its distinct possibilities and advantages. Design and strength being equal in both instances, the determining factors should be the cost of more welding against the cost of heavier plates, and secondly, the possible machining time that can be saved either way. If one heavy plate can combine several expensive bosses, and perhaps a necessary machining pad, there is no doubt but what it should be used. Very often this one heavy plate provides the added rigidity where the structure would be entirely lacking without it. The strength of the material we are dealing with has been allowed to cover too many sins. Rigidity should not be mistaken for strength. Each is individual and the structure should be so designed as to receive the greatest benefit from both.

Light plates are highly effective for ribbing, and wherever support plates are necessary. If forming facilities are available, bent plates should be used. They serve a threefold purpose; torch cutting is eliminated, welding is reduced to a minimum, and the product itself is made better appearing. This elimination of extra welding brings us to the point we are trying to reach, that of a welded member with very little welding. When using light plates for cross ribbing, it is very often better to rough plane these to the inside dimension so that not only is less care needed in lining up, but a straighter, much better structure is the result. This results in time-saving in machining because it is possible to control the amount left for finish, and very often one finish cut is all that is necessary.

Overhanging plates should be avoided wherever possible, and if they are absolutely necessary, they should be well supported with ribs or triangles. Every effort should be made to either discourage or at least allow for pulling over during a welding operation. As in the case of steel castings during the pouring operation, temporary cross ribbing should be resorted to. These ribs tend to hold the member straight while welding is being done, and they can be cut away when the structure has cooled off, after which it may be stress annealed. The method of applying these temporary cross ribs may be worked out with the man supervising the tack welding. After a structure has been tacked together, it is good practice to spend a little time and go over the entire structure, not only for a final check on design, but to make certain that it will hold its shape in the process of welding.

The designer must consider the possibilities of constructing the main members in such a way as to leave a minimum amount of scrap in torch cutting. Very often a slight change in the shape of a large housing plate will permit several smaller plates to be cut from the same stock.

The article so far has dealt with fundamentals involving methods of designing given welded structures so that time can be saved in the shop, in the cutting, welding and machining departments. We have confined ourselves to welded structures consisting of steel plates throughout. No other material has been considered than rolled steel. There is, however, an important item that is not only a cost reducing factor, but one that must be considered in any welded structure of considerable



A Completed #1042 Verson Allsteel Eccentric Press. Notice the Sectional Construction for Easier Handling; the Use of Bent Plate; and the Beauty of Its Trim Appearance

weight. It is the method of combining steel castings with steel plates to the best advantage of the structure with regard to design, construction and economy of manufacture. Whether to weld or to cast, is far easier to decide than whether to use steel plate only, or to combine the two.

It should not be very difficult to determine whether the design or structure warrants cast steel or welded construction. To begin with, the first consideration should be quantity. If there are only one or two, or half a dozen involved, the pattern cost could not be spread over a great enough area to warrant the use of cast steel. If a greater quantity is desired, and the member is not too cumbersome or large, then cast steel would probably be cheaper. Even with the greater quantity, however, there are other factors to consider. One is the element of time, and in many cases this is the deciding factor. In welded construction, it is possible to have the entire member cut, welded normalized and machined before the pattern is made. The other factor is the equipment which the shop has for handling a general run of welding work. If the shop is equipped with proper rolling and forming machines, then the cost of cutting and welding is reduced so greatly that even on very small members, the cost is far below that of steel castings. The reason for this is that with a forming machine, it is possible to bend up a box section from one piece of steel, and only leave one place to weld, thereby saving three torch cuts and three welds. Furthermore, bending of plates offers another great argument in the favor of welding, and that is that a bent plate structure having rounded corners improves the appearance to such extent that cast steel cannot compare with it on this point.

In heavier members weighing several tons, the choice of using steel plates or steel castings is easily made, since the quantity would be naturally limited, and the pattern cost would be prohibitive. Even were the pattern cost entirely disregarded, one must consider the fact that in heavy structures the welded member would be the stronger of the two, since it would be more homogenous, and would certainly not have any blow-holes in the heavier sections. If further inducement is necessary before making this choice, the cost per pound method of figuring should suffice. Since the design would be almost identical in the two, it is only a case of estimating the weight of steel castings at so much a pound, against the estimated weight of the steel plates plus the cutting and welding costs. Invariably, in heavy members, the construction will favor welded plate design, since it is only a matter of using so much plate at about two cents per pound as compared to steel castings at triple the cost or more.

If the analysis designates the use of a steel casting, the subject is closed. However, if welded design is decided upon, then the structure offers other problems which can be handled in one of two ways; it may be entirely constructed of steel plates, or it may be a combination of steel plates, and steel castings, both combined into a rigid unit to the greatest benefit of the design. The problem now is to determine just exactly where and why a steel casting insert should be used, instead of building up these small sections of welded steel and inserting them in their proper places.

Steel castings should be used in combination with welded steel when the general design as a whole will be greatly simplified by their use. By that, I mean that by resorting to one single, simple casting, many small pieces can be eliminated. Although small pieces of scrap may be used in constructing this one item in question, it may still be more costly than the use of a steel casting. To begin with, no matter how much scrap a firm has on the floor, there is seldom a piece that can be used without additional torch cutting. Furthermore, it is always costly to handle small pieces, often having to bevel by hand torch before welding, and then finally having to clean it up and chip off the rough spots before tacking it to the larger unit.

To emphasize the point which I am trying to convey, let us take the side of a small structure resembling a speed reducer with three parallel bores. In order to provide proper bearing for the three shafts, it is only natural that the member be provided with bosses of sufficient length to support these shafts. In the welded design, it will be necessary to first cut off these bosses by saw, face them in the lathe, rough drill them in a drill press, and finally tack them in place.

More often than not, these bosses will have to be supported with suitable triangles or ribs. These bosses involve labor aside from the cutting and welding departments and this labor is often overlooked. If a light steel casting were used, it could be so designed that the three bosses would be combined into one member by means of three ribs. The holes could, of course, be cored and so save valuable machine tool labor. In this one instance, by combining the three bosses into a flat plate casting, it can be welded in place without concentrating the welds in a small area, as would be the case in three single bosses. It all sums up to the fact that if we can save the labor of saw cutting, facing in the lathe, drilling and additional torch cutting, by using a simple steel casting, then it should be used.

Suppose we consider a heavy steel welded member having certain bearings that are of the split cap design. Let us assume that these bearings carry unusually large diameter shafts, and that each bearing is about 12 inches long. To build a 12 inch long bearing of steel plates, it would be necessary to use either three 4-inch plates, two 6-inch plates or four 3-inch plates. These plates would all have to be first cut to shape, bevelled all around and then welded together. It would also be necessary to weld a half ring on each in order to provide proper tool clearance when facing the ends of the bearings. After all these plates have been welded together, the unit will, no doubt, have to be rough machined before it can be welded into its proper place. Against all this fitting of plates and rough machining, a single steel casting is more favorable, not only from the standpoint of lowered cost, but from the point that is probably stronger, since in this case it is more homogenous. Disregarding the strength of either material, they can both be easily figured for cost. All that is necessary is to take the estimated rough weight of the several pieces of steel at two cents a pound, plus so many feet of welding, plus time necessary for rough machining and tacking, against the estimated weight of the steel casting at so much per pound. Even if the figures slightly favor the welded design, as stated before, the casting should be used.

Aside from general illustrations and examples, it is rather difficult to set down definite rules of just where to use a steel casting with a steel plate, or where to use steel plate entirely. The primary consideration should be, and always is, *cost*. It is only a matter of figuring estimated weights and their respective costs per pound. Then there is the matter of simplifying the handling of the design by combining several small pieces into one steel cast member. Third, as in the case of a bearing seat, the casting would be favored because of strength. By strength, I do not mean that a steel casting is stronger than the plate, but that in this particular instance, where the casting is one piece, and the welded member probably four or five pieces, the casting would answer the purpose better.

Qualifying Welders of Silicon Bronze

According to Paragraph 69 of the A. S. M. E. Unfired Pressure Vessel Code

By CHARLES W. REID†

THE welding experience of our Company began about twenty years ago when it realized the potential advantages of the new art in the construction of heat exchange equipment.

Manufacturing water heater and other heat exchange equipment, most of which handle water and other liquids at high temperatures, the heavy corrosion factor naturally led them to the use of non-ferrous metals and alloys. Among the alloys, Silicon Bronze is probably the most outstanding, combining as it does the tensile strength of steel with the non-corrosive quality of copper.

However, to speak of Silicon Bronze is like speaking of steel when one of its numerous alloys is referred to.

There are a number of different brands of Silicon Bronze. They vary to only a very slight degree in composition, but even this slight difference makes it necessary to vary the welding technique to suit each individual brand. In order to qualify our welders under the A. S. M. E. Code and secure the approval of The Hartford Steam Boiler Inspection and Insurance Company, it was necessary to adopt one particular brand, and Everdur was selected. While this metal has a tensile strength of 55,000 lb. the A. S. M. E. Code permits a unit of only 9000 lb. per square inch, with 80% joint efficiency, and all calculations as to thickness of material, etc., must be based on these figures. The requirements as to flanging and dishing of heads, radius of knuckle, etc., are the same as for steel heads of equal thickness and diameter.

In common with all alloys, the Silicon Bronzes are extremely sensitive to even slight changes of temperature in welding, so that a very careful and detailed technique must be followed, and the closest supervision is required.

The following is the A. S. M. E. ruling according to Case No. 715 of the Unfired Pressure Vessel Code:

INQUIRY: Will unfired pressure vessels fabricated by fusion welding under Class 2 test requirements meet the Code provisions if the base metal is a high-strength copper alloy of the following chemical and physical properties?

Copper	96 per cent (approx.)
Silicon	3 per cent (approx.)
Manganese	1 per cent (approx.)
Impurities, not over	0.5 per cent
Tensile strength, lb. per sq. in., min.	52,000
Yield strength, lb. per sq. in., min.	18,000
Elongation in 2 in., min.	65 per cent
Reduction in area, min.	70 per cent

† Superintendent, The Patterson-Kelley Company.

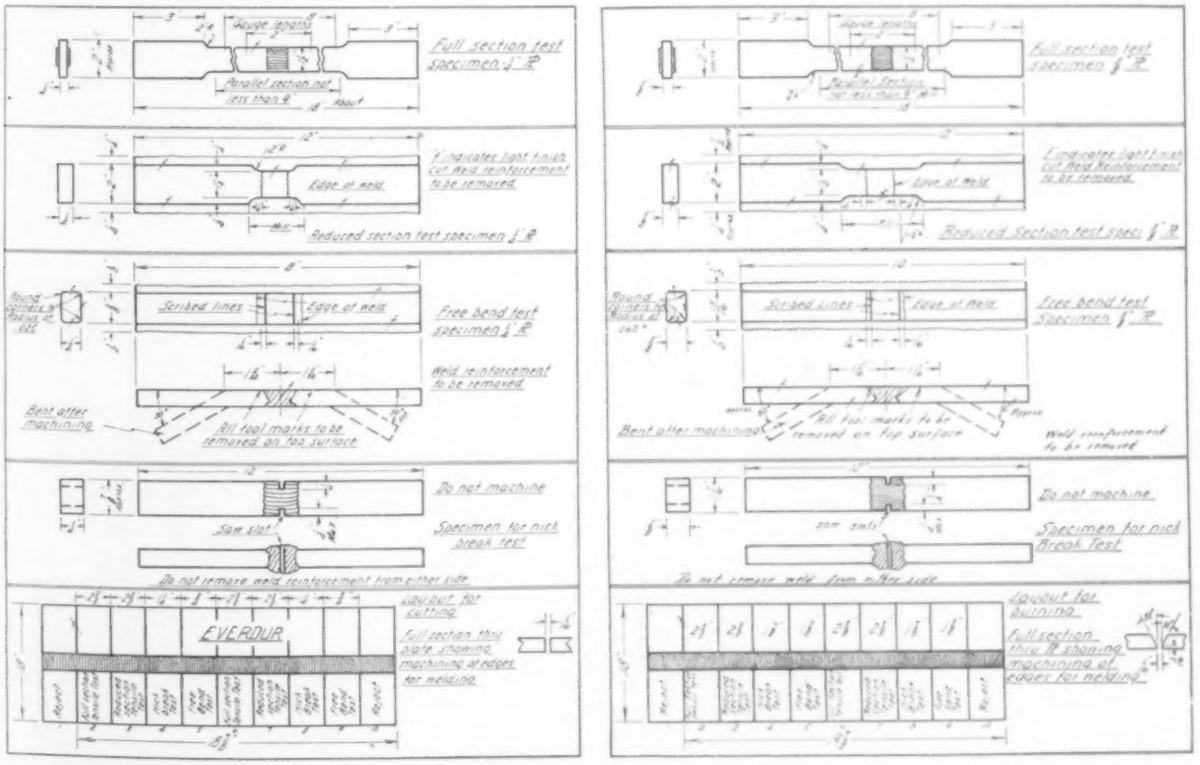

Gauge points
Full section test specimen
Parallel section not less than
Edge of weld
Reduced section test specimen
Scribed lines
Free bend test specimen
Weld reinforcement to be removed
Bent after machining
All tool marks to be removed on top surface
Do not machine
Saw slot
Specimen for nick break test
Do not remove weld reinforcement from either side
EVERDUR
Layout for cutting
Full section thru plate showing machining of edges for welding
Layout for burning

Fig. 1

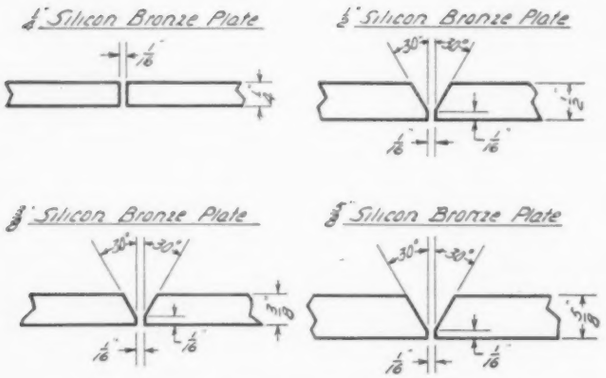


Fig. 2—Preparation of Everdur Plates before Welding

The plate is hot rolled and annealed, and is free from injurious defects and flaws, and has a workmanlike finish.

REPLY: It is the opinion of the Committee that annealed copper-alloy plates or sheets having the chemical composition and minimum physical properties specified in the inquiry, may be used for the construction of unfired pressure vessels by fusion welding under the general requirements of Class 2 construction, the exceptions from which are that the elongation as determined by the free bend test shall not be less than 40 per cent, that the tensile strength shall not be less than that of the base metal, and that stress-relieving is not required for this kind of annealed material. The operation temperature shall not exceed 406 F. The maximum allowable unit working stress shall not exceed 9000 lb. per sq. in. for the material and (S X E) 7200 lb. for joints welded as above specified.

This and other Silicon Bronzes can be successfully welded either by the Metallic Arc method, or the Carbon Arc method. The Carbon Arc method is more easily controlled when welding off the horizontal position, and this method was adopted for qualifying our welders.

The following covers the specification of material and procedure adopted by our Company.

Specifications for Fusion Welding of Unfired Pressure Vessels

Base Metal.—The material for the base plates to be high strength Copper Alloy of the following chemical and physical properties and trade name "Everdur:"

Copper	96 per cent (approx.)
Silicon	3 per cent (approx.)
Manganese	1 per cent (approx.)
Impurities	0.5 per cent
Tensile strength	52,800 lb. per sq. in. minimum
Yield point	18,000 lb. per sq. in. minimum
Elongation	65 per cent in 2 inches minimum
Reduction in area	70 per cent minimum

Process.—The welding shall be done by the carbon arc process.

Filler Metal.—The filler metal shall be of approximately the same physical properties as the base plates.

Welding Groove.—The edges of the plate shall be machined to form a welding groove as indicated in Figs. 1 and 2.

Cleaning of Groove.—Prior to welding, the edges of the plate and the surfaces adjacent shall be thoroughly cleaned of all scale, impurities and grease or oil.

PROCEDURE OF WELDING EVERDUR PLATES

Metal Thks. Inches	No. Beads		Weld Rod	Open Circuit Amps.	Open Circuit Volts.	Closed Welding Circuit Amps.	Closed Welding Circuit Volts.	Carbon Dia.	Remarks
3/16	2	1	3/16"	200	75	120	30	5/16"	Butt Weld. Edges of plate to be open 1/16". Dust lightly with Everdur Flux.
		2	3/16"	200	75	120	30	5/16"	
1/4"	2	1	3/16"	200	95	200	30	3/8"	Ditto
		2	3/16"	200	95	200	30	3/8"	
5/16"	3	1	5/32"	300	95	300	30	3/8"	Butt Weld. Edges of plate to be open 1/16". Dust lightly with Everdur Flux.
		2	3/16"	200	85	175	30	3/8"	
		3	3/16"	300	85	250	30	3/8	
3/8"	3	1	5/32"	300	95	300	30	3/8	Ditto
		2	3/16"	200	85	175	30	3/8	
		3	3/16"	300	85	250	30	3/8	
1/2" SINGLE V	5	1	1/8"	100	95	140	30	5/16	Butt Weld. Dust lightly with Everdur Flux.
		2	5/32"	200	95	200	30	3/8	
		3	5/32"	200	95	200	30	3/8	
		4	3/16"	300	95	300	30	3/8	
		5	3/16"	300	95	300	30	3/8	
5/8"	6	1	1/8"	100	95	140	30	5/16	Ditto
		2	5/32"	200	95	200	30	3/8	
		3	5/32"	200	95	200	30	3/8	
		4	3/16"	300	95	300	30	3/8	
		5	3/16"	300	95	300	30	3/8	
		6	3/16"	300	95	300	30	3/8	

Fig. 3

Fig. 4—All-Welded Everdur Tank

Number of Beads of Welding.—The number of beads of welding used for various thicknesses of plate shall be substantially as shown in Fig. 3.

Current Characteristics.—Current shall be D.C. from a motor generator. The amperage and volt values used for the different beads of welding shall be substantially as shown in Fig. 3. The plate to be welded shall be on the positive side of the line.

Cleaning.—All slag or flux remaining on any bead of welding shall be removed before laying down the next successive bead of welding.

Defects.—If any cracks or blow-holes occur on the surface of any bead of welding, they shall be chipped out with a round-nosed chisel to remove defects and present such a surface that proper fusion may be obtained with the next successive bead of welding.

Peening.—Each bead of welding, with the exception of the first bead and each outside bead, shall be moderately peened with a blunt tool to relieve residual stresses in the weld metal.

Treatment of the Under Side of Groove.—Prior to welding the under or second side of the welding groove, all oxidized metal which has dripped through shall be removed, and the groove shall be opened at least one sixteenth of an inch ($^1/_{16}$ in.) or it is to be chipped to allow full and complete penetration.

Changes.—Changes in these specifications may be permitted if such changes have the approval of the Hartford Steam Boiler Inspection and Insurance Company.

It will be noted that where the plates are beveled, a single bevel is used instead of a double bevel. This is because it is more practical to use this type of joint in the manufacture of heaters and heat exchangers when heavy plates are used.

Everdur and the other Silicon Bronzes can be welded to steel, but exceptional care must be used or the steel will come up through the weld metal, and the weld will be porous. Should a leak develop during the test, it must not be caulked, but chipped out and rewelded.

Model Aids in Machine Tool Design*

By FRED L. PLUMMER†

THE proper design of any machine or structure requires that we predict what forces will act upon the completed assembly and the conditions under which those forces will be active. It is then necessary that we determine the stresses and distortion which will be created in the structure by the applied forces. Finally, we must select the material and determine the amount and shape of that material, which will most efficiently provide a safe and useful service life for the projected machine or structure. Included in this final step is the selection and design of proper connections so that the parts of the structure may be assembled and act as a unit.

Early methods of fabrication are largely responsible for a design tradition based on empirical and "rule of thumb" procedures. Newer methods of fabrication together with the increased use of high strength and light weight metals, make more exact methods of analysis and design essential, if our machines and structures are to be economical and at the same time provide satisfactory service records.

The designer of machine tools will find many types of model studies to be of great aid in executing his designs. Three dimensional models built of identical or similar materials may be loaded and tested just as the full scale structure might be tested. Models made of brittle material having a constant stress-strain relationship up to ultimate strength are useful in determining stresses on complicated sections. Rubber models may be used to demonstrate and study distortions. Several useful analogies have been developed which enable the designer to solve stress distribution problems by observation of electrical, hydraulic or other phenomena.

The photoelastic method is especially valuable to the designer of machines because it enables him to determine and, therefore, avoid the points of stress concentration which have so frequently resulted in fatigue failures of machines which involve reciprocating or rotating parts.

* From a paper presented before the Cleveland Section of the AMERICAN WELDING SOCIETY, December 11, 1936.

† Assoc. Prof. Structural Engineering, Case School of Applied Science.

Question and Answer Column

Preheating Rail-Ends for Arc Welding

Question.—"Isn't it better to preheat rail ends before electric welding them, that is, building up rail joints with the electric arc?"

Answer.—C. A. Daley, M-of-W Specialist, Air Reduction Sales Company—"I do not agree that it is better not to preheat rail ends when building them up with electric arc as stated in the reply to the above question.

"If the rail is not preheated, the mass of cold parent metal acts as a quench on the added metal, forming a martensite structure of the steel at the junction of the weld. Incipient cracks or checks result also from the sudden cooling of the added metal.

"Preheating does not eliminate these undesirable conditions, but it does help the situation some, that is, the rail ends will not chip or shell out quite as soon under traffic."

Metallurgical Problems of Welding in the Automobile Industry*

By ARMAND DI GIULIO†

THE public in general regards the developments of the last ten years of progress in the manufacture of cars as represented primarily by the radical changes of the outside appearance or shape, the greater safety of operation, as well as improvement in the performance of the power plant, specifically the increased speed and the greater economy. Yet, when one compares the present-day, all-steel body with the body of 1927, for instance, one is actually considering two entirely different things. There is no doubt that the roomier, all-steel bodies and the safer integral construction exemplified by the Lincoln-Zephyr could not have been built if welding had not permitted abandoning the composite wood and steel construction of yesterday.

The extensive use of welding in the Ford V-8 may be shown by the following figures: in a Tudor sedan, there are approximately 3800 welds in the body and chassis exclusive of the welds in component parts such as horns, generator, lamps, etc.; of all these welds 92% are spot weldings, 3% arc weldings, 2% oxyacetylene weldings and the remaining 3% is made up of resistance butt-weldings and seam weldings. These figures, however, do not actually give a true comparison between the various welding processes because they are based on number of welds and not on inches of surface welded. However, to calculate the surface of all the welds in an automobile would be almost an impossible task.

The very wide application of welding has been dictated by sound engineering principles. First of all, welding joins parts into one whole, thus adding strength and eliminating rattle and wear. Second, welding reduces unnecessary weight. Third, the use of automatic welding machines has reduced or eliminated the human factor and consistent good welds can be obtained. Fourth, welding has materially reduced the cost of production.

For the sake of clarity, we may define welding as the process of uniting metals by means of heat and pressure or by heat alone in such a way that the resulting joint will develop strength and transmit stress. The common characteristic of all welding processes is that the metal is heated, and, with or without the aid of external pressure, the two metal surfaces cohere.

The various welding processes may be grouped in two classes:

Class A.—Those processes in which the metals are heated well above their melting point, and their union brought about in the liquid state.

Class B.—Those processes in which the metals are heated to the plastic state just below the melting point at which time the application of pressure causes the union to take place.

Since the above classification differentiates between processes based on widely different principles, a more detailed subdivision of each class is necessary in order to describe the many welding processes used in the making of the present-day automobile.

Class A welding includes the following welding processes: (1) gas welding, (2) electric arc welding, (3) brazing and (4) thermit welding. As has already been mentioned, in this class of welding, the union is accomplished by heating the metals above their melting points. The difference between the processes is the source of heat, which may be supplied by: (*a*) the combustion of gaseous fuel, such as oxyacetylene mixtures, (*b*) the discharge of the electric arc and (*c*) the exothermic reaction which takes place when aluminum powder and iron oxide (Fe_3O_4) are ignited.

Without entering into a detailed description of each of these processes, we may consider the metallurgical factors upon which depend the quality of the weld. The heating of the metals above their melting points, and subsequent cooling, results in a sequence of conditions in which the chemical and physical properties of the metals undergo marked changes. In the automobile industry, we are concerned mostly with the welding of steel, and, in order to understand what takes place when two pieces of steel are welded, we must refer briefly to the metastable Fe-C diagram of Fig. 1. Let us assume that the steel in question is a hypo-eutectoid steel; that is, it contains less than 0.87% carbon. As we know practically all of the welds in the automobile are made with material of this type. If, for the sake of illustration, we consider a steel containing 0.4% carbon, the cycle of changes during welding may be summarized as follows: This steel, in the annealed condition, consists of ferrite and pearlite in about equal proportions; ferrite, or alpha iron, is the magnetic body-centered phase, pearlite is a eutectoid mixture of ferrite and cementite or carbide of iron. The carbon present in the steel is only slightly soluble in ferrite, and, at room temperature, is present in the cementite of the pearlite. As this steel is heated from room temperature, no phase change takes place until the temperature of about 1335° F. is reached. At this point the eutectoid temperature, pearlite becomes unstable and transforms into a new phase which is austenite, the face-centered cubic lattice. In this phase, carbon goes into solution to the extent represented by point *E* corresponding to 1.7%. At this temperature, ferrite also begins to transform into the non-magnetic phase, and upon regarding the Ar_3 line, changes into austenite. Further increase in temperature within the region of austenite results in an increase in the grain size until the line *J-E* is reached, at which point melting begins. Within the area *J-E* and *B-C*, melting continues until a point on line *J-B* is reached at which temperature (about 2700° F.) the austenite decomposes into delta iron, plus liquid. Above line *A-B-C*, the alloy is totally molten. Further increase in temperature above this point does not cause any change. On the other hand, reactions be-

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† Chem. & Met. Dept., Ford Motor Company.

tween the metal and the slag, and between the metal and the gases present, take place primarily when the metal is in the molten state. These reactions are very similar to those which take place in the open hearth furnace and are responsible for the chemical changes which occur both in the electrode and in the metal to be welded.

Numerous researches have established the fact that all the possible sources of heat used in fusion welding cause oxidation; therefore, care must be taken in order to minimize this effect. For instance, carbon may be oxidized to the extent of 50% of the original amount in steels containing from 0.25 to 0.48% carbon. The amount of carbon "burned" depends primarily upon the type of electrode used and on the nature of the atmosphere surrounding the weld. Of the other elements present in steel, silicon is easily oxidized; next is manganese. Besides these changes in the metals to be welded, the gas content of the deposited metal is also affected by the nature of the electrode; i.e., a bare electrode deposits about 0.3% oxygen and about 0.12% nitrogen, while a shielded arc electrode will deposit material containing about 0.06% oxygen and 0.018% nitrogen. Of course, in the case of gas welding, the type of flame used will greatly determine the amount of gas left in the weld. In general, it may be said that stronger and sounder weldings are produced with shielded electrodes.

Referring again to the iron carbon diagram, when cooling begins, a reverse process from the one described takes place. The central portion of the weld, which has been heated above its melting point, will again transform at line *A-B-C* into delta iron, which reacts with any remaining liquid to form austenite, and when a temperature, indicated by *J-E* is reached, the metal will be solid and completely in the austenitic state. During the solidification of the steel, a contraction in volume takes place accompanied by evolution of gases which were dissolved in the molten steel. It is during this period that gas bubbles and pipes are formed. At this high temperature, some recrystallization takes place in the so-called "granulated zone." As the temperature is lowered, and as the Ar_3 line is reached pro-

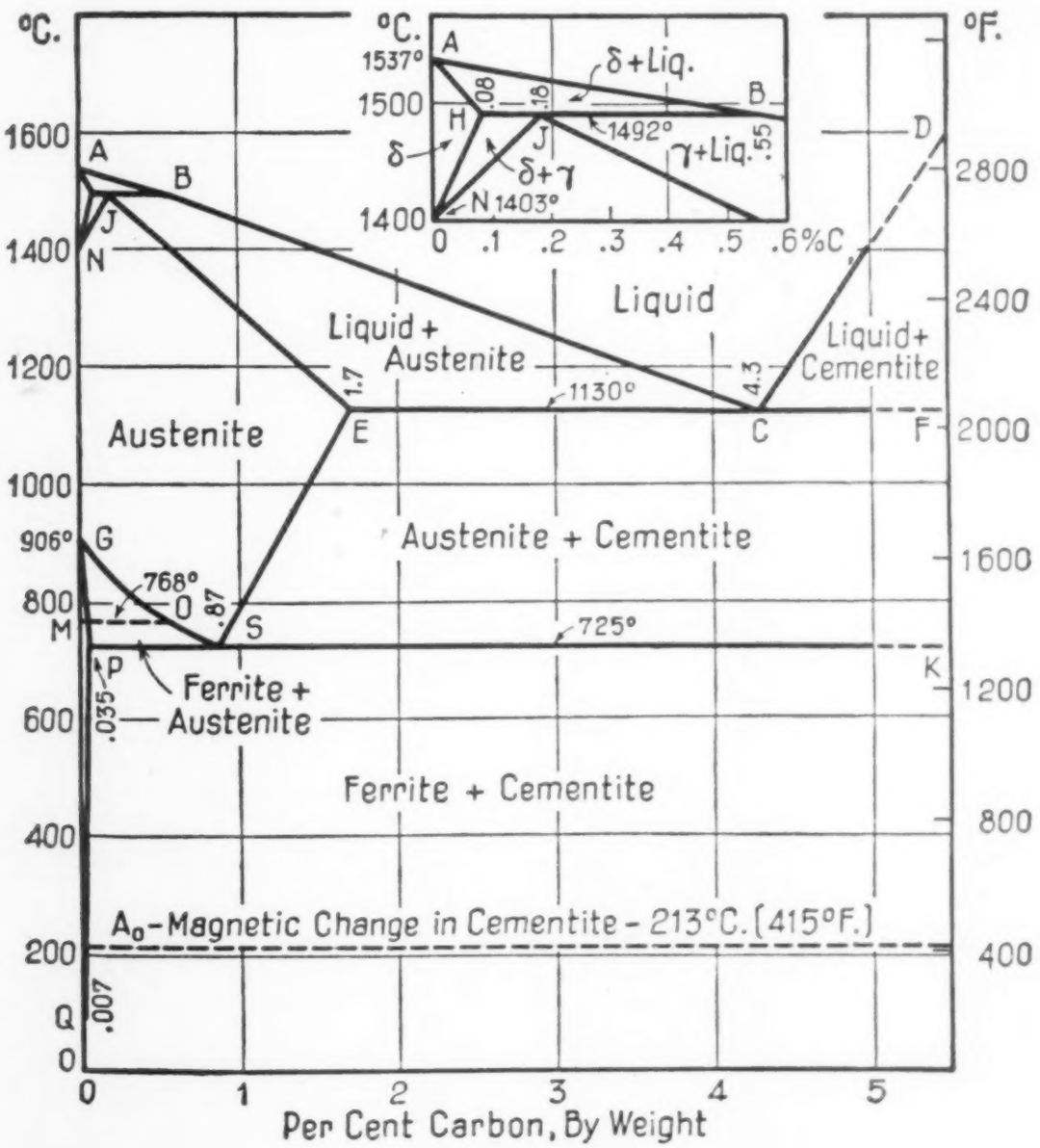
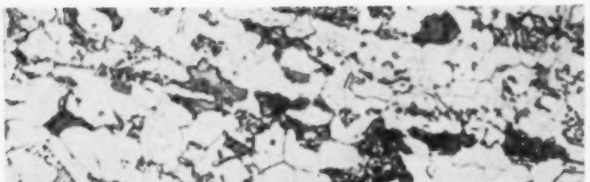
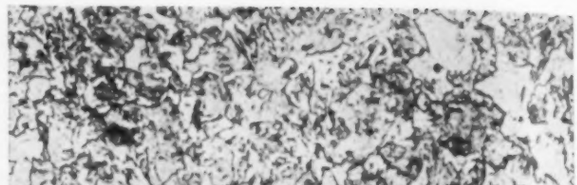
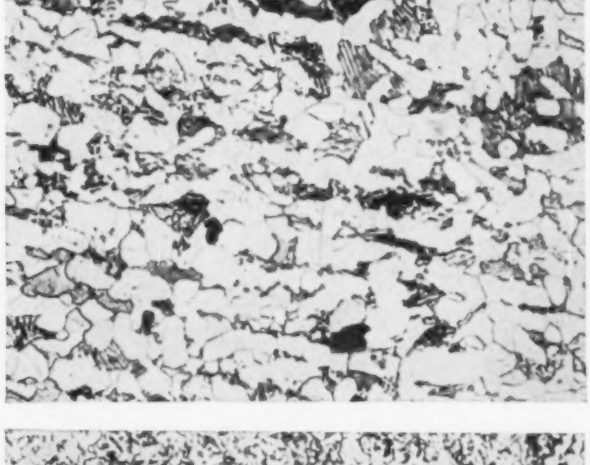
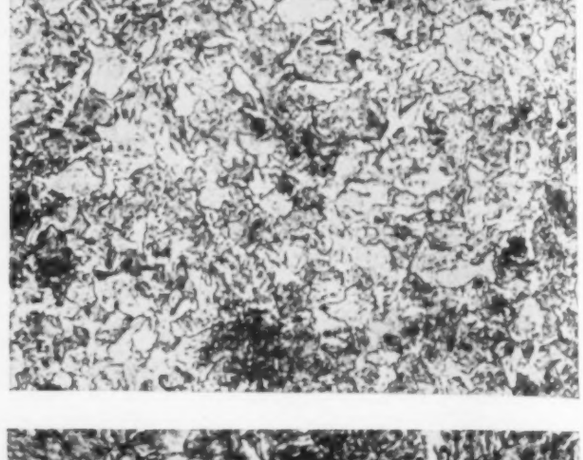


Fig. 1—Iron-Carbon Diagram









(Top) Photomicrograph 1. X 500
Structure of Hot-Rolled Tube of Front Radius Rod

(Bottom) Photomicrograph 2. X 500
Structure of Hot-Rolled Tube of Front Radius Rod Recrystallized Zone

(Top) Photomicrograph 3. X 500
Zone Heated High in the Austenitic Range

(Bottom) Photomicrograph 4. X 500. Weld

eutectoid ferrite starts to form; this ferrite phase increases until the temperature of 1335° F. is reached at which place the remaining austenite is totally transformed into pearlite.

At this point, however, we must consider the fact that in any fusion welding process, heating is accomplished at a very rapid and in a relatively small area; consequently, due to the thermal conductivity of the metal, there is present a temperature gradient which covers a zone extending from the melting point of steel at the weld to a point unaffected by the heating. On cooling, heat is dissipated from the central part of the weld at a faster rate than from the outer portions. It is within this uneven temperature zone that all the changes illustrated by the iron-carbon diagram take place at a very rapid rate. Equilibrium conditions are not reached; therefore, the structure of the weld and of the metal adjacent to it show practically all of the stages of transformation for the steel involved.

To see what takes place, let us examine under the microscope a typical arc weld. This sample was taken from the weld of a Ford front radius rod made from a steel flat, or a composition similar to S.A.E. 1040 rolled into a tube. The tubes were next placed in a continuous arc-welding machine in which the seam was welded at the rate of about one inch per second using an electrode of the following composition:

C: 0.10 Max.; Mn: 0.20 Max.; S: 0.02 Max.; P: 0.03 Max.

The following photomicrographs show the structure of a cross section of the weld. In Photomicrograph No. 1, we see the typical structure of a hot-rolled steel in the zone not affected by the heating of the metal; Photomicrograph No. 2 shows a zone which was heated

not much above the Ar_1 range where recrystallization has taken place; Photomicrograph No. 3 indicates the structure of a zone whose temperature was well within the austenitic range, whose large grains were produced on cooling from this high temperature; Photomicrograph No. 4 shows the weld itself, at one side the high-carbon steel of the type, and at the other the low-carbon steel of the electrode. From the structure of the high-carbon steel, it can be seen that the cooling was very fast because the transformation from austenite to ferrite and pearlite has produced a very fine pearlite surrounded by ferrite. If the cooling had been slower, the temperature of transformation would not have depressed and the resulting pearlite would have had more of the appearance of the conventional plate-like structure which is easily recognized even at a low magnification; Photomicrograph No. 5 illustrates the electrode metal in the as-cast condition as indicated by the large columnar crystals.

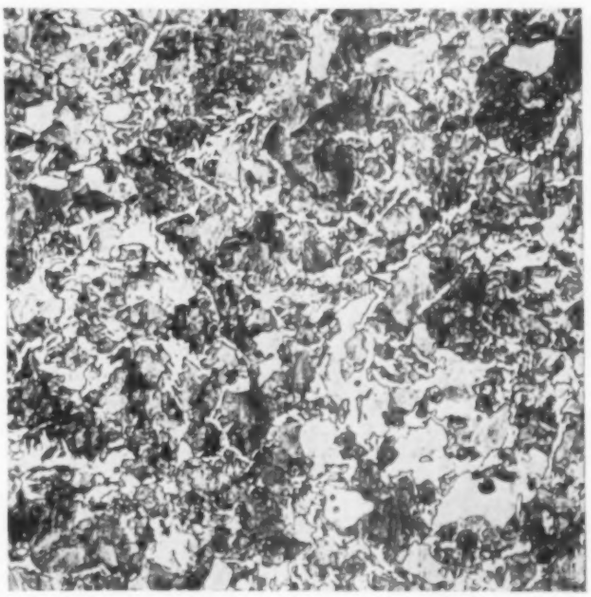
There are other applications of arc welding which are very suitable for important parts of the car; for instance, the drive shaft which consists of a tube at either end of which is inserted a splice, and the welding of the 3 pieces is made in a machine of the rotating type using a bare electrode. Another application is to be found in the assembly of the rear axle housing of commercial cars in which case two forgings, a yoke and a flange are welded to a seamless tube in an automatic revolving machine where the two welds are produced simultaneously.

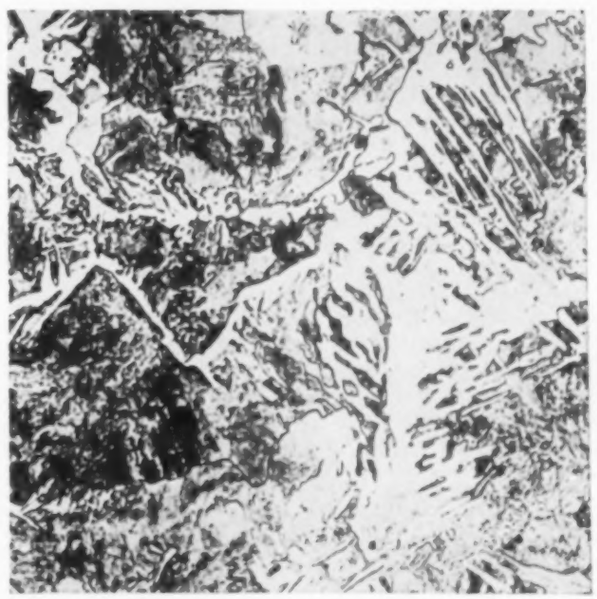
Gas welding finds only a limited number of applications in the production of the 1937 Ford. These are to be found mostly in joints between the body proper and the floor panel, and in places where other welding machines would be impossible to be used.

Class B, the pressure-resistance type of welding, as mentioned earlier in the paper, is the one which finds its greatest application in the automobile industry. In this class, the parts to be united are brought to the plastic stage by the passage of electric current, heat being generated by the resistance offered by the metal. This heat is accompanied by the exertion of mechanical pressure which helps to cause the union of the parts. It has been stated that the heavy localized heat and pressure cause recrystallization of the metal followed by grain growth which permits the grains to grow together. This explanation seems plausible when one considers the fact that, in all resistance welding, mechanical pressure is applied; thus, the heavy localized pressure on a small area will provide the strain necessary for recrystallization. The resistance type of welding is by far the most important for the automobile industry because of its extensive application and the large capital invested. Its greatest advantages are: (1) a smoother finish, and (2) a quicker and more flexible method of fabrication of assemblies.

In the earlier days, most of the resistance welding was done by means of stationary hand operated machines, but lately the tendency is, especially in the case of spot welding, to use the more flexible portable welders in which the welding is accomplished by hand operated

Photomicrograph No. 5. X 500. Electrode Metal





(Top) Photomicrograph 6. X 500
Structure of Forging after Heat Treatment

(Bottom) Photomicrograph 7. X 500
Structure of Weld Between Tube and Forging

welding tools through which the pressure applied and the amount of current are automatically controlled.

The resistance welding process is further subdivided into various catagories, namely (*A*) Resistance-Butt Welding, (*B*) Projection Welding, (*C*) Seam Welding and (*D*) Spot Welding.

(*A*) *Resistance-Butt Welding* consists in gripping the pieces between two electrodes or "jaws" and in pressing the parts together while the electric current causes heating at the surface of contact. The heat generated is high enough to bring the metal to a plastic state and with the proper pressure very good welds are obtained. In some applications, the pressure is so regulated as to produce an arcing effect which results in a flash welding. Resistance-butt welding finds only a limited number of applications in the making of the Ford V-8; however, it is used on important parts such as (1) welding of the front radius rod feet, and (2) welding of the left and right members of the radius rod.

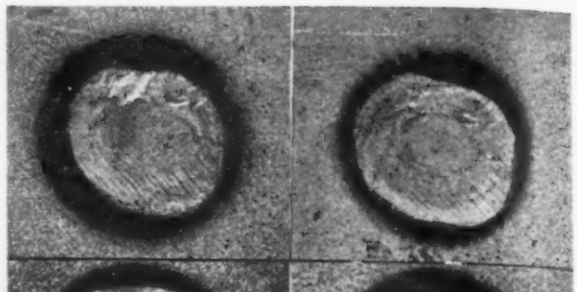
(1) In the welding of the front radius rod, at the right and left end are welded two forgings, the so-called right and left foot, made of steel similar in composition to S.A.E. 1040. These forgings are given a quench and draw treatment before being welded. Both static and fatigue tests are performed daily to ascertain that the weldings do not in any way impair the desired physical properties of the assembly. The structure of a weld of this type is seen in the following photomicrographs. In Photomicrograph No. 6 is seen the structure of the forgings, while Photomicrograph No. 7 shows the structure of the weld proper. Recalling the structure of the arc weld of Photomicrograph No. 4, one can notice that there is a considerable difference between the structures of the two welds. In the present case, the grains are well defined and much larger. It is evident that, although the temperature at this weld was never as high as in the previous one, the mass of metal heated was such that cooling took place at a much slower rate; thus, the transformation of austenite to ferrite and pearlite approached more nearly equilibrium conditions.

(2) In the welding of the right and left members of the radius rods, the two parts are united to the yoke which is a steel forging similar in composition to S.A.E. 1030.

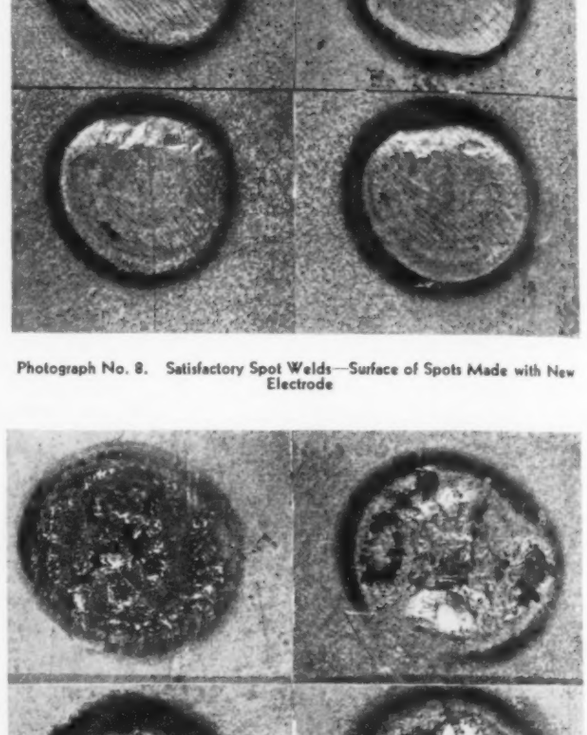
(*B*) *Projection Welding* takes its name from the fact that small projections are stamped on one or both pieces to be welded in order to localize the flow of current through the small areas. This process finds its application in cases where small parts are welded together or to a larger piece; also, it can be used successfully for thicknesses up to $^1/_4$ of an inch. In the Ford passenger car, application of projection welding are found in various assemblies of the body, such as (1) the hood hinge bracket base is welded to the retainer, (2) the head light unit retainer is welded to the front fender, and (3) the rear reinforcing assembly is welded to the hood top.

(*C*) *In Seam Welding* the electrodes take the form of rolls, by means of which pressure is applied. While this pressure is continuous, the current is regulated by means of an interrupter so that a series of overlapping welds is produced on the two sheets of steel. Seam welding may be considered as a continuous spot welding process in which each successive point of contact at the periphery of the rolls is the electrode. A typical application of seam welding is in the construction of the gas tank which consists of tern plate welded in a series of stationary machines.

(*D*) *In Spot Welding* the pieces to be welded are placed between two electrodes whose tips are relatively small and a large current of low voltage is passed through. Heavy pressure is applied at the electrodes and, immediately after, the current is passed for a short interval of time; the pressure being maintained momentarily after the current has been shut off. In modern automatic welding machines, elaborate timing devices permit close regulation of pressure and current which assure welds of uniform quality. It would be almost impossible to enumerate all the parts of the 1937 Ford which are joined by means of spot welding, but as I have already pointed out, spot welding constitutes by far the most used process of welding and its use is increasing continuously.



Photograph No. 8. Satisfactory Spot Welds—Surface of Spots Made with New Electrode



Photograph No. 9. Uneven Surface Due to Poor Electrode Tip—Surface of Spots Made with "Mushroomed" Electrode

The chief metallurgical problem arising in connection with electric resistance welding is the choice of the proper electrode material. The quality of the weld, as well as the performance of the welding machine, depend primarily on the electrodes used. Briefly summarized metals or alloys suitable for making resistance welding electrodes must possess the following properties: (1) high-electrical conductivity, (2) high-thermal conductivity, (3) a combination of hardness, impact and wear resistance and (4) retention of these properties at the relatively high operating temperatures.

(*1*) *High-Electrical Conductivity* is required in order to

decrease the resistance and to prevent over-heating at the point of contact between the work and the electrode.

(2) *High-Thermal Conductivity* is necessary to keep the electrode tips as cold as possible by dissipating the heat generated during welding. In most spot welding machines, water cooling is provided either by the use of hollow electrodes or by circulating water around them.

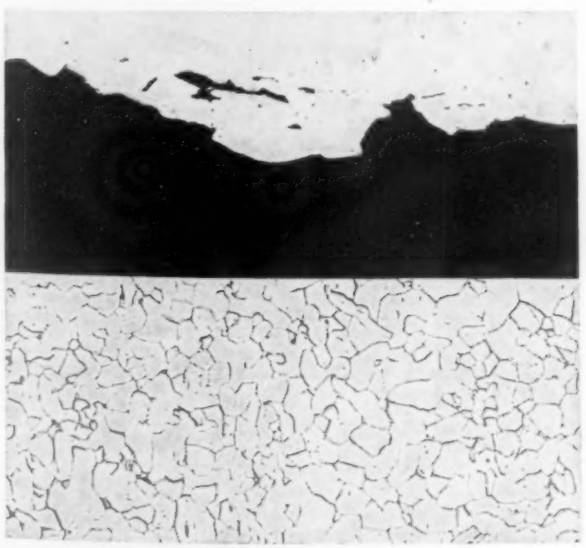
(3) *A Combination of Hardness, Impact and Wear Resistance* and

(4) *Retention of These Properties* are necessary because resistance welding, in general, and primarily spot welding, makes use of relatively high pressure applied suddenly and the electrode must be able to withstand such loads and transmit pressure to the works as uniformly as possible. It is necessary, therefore, that the area of contact between the electrodes and the pieces be constant. If the tip area becomes larger and uneven, the unit pressure becomes lower and a poor weld is obtained; also, considerable time is lost in redressing the electrodes. One can hardly over-emphasize the fact that the electrode tip must be smooth and of uniform area to insure good welds. This point is better illustrated by the photographs of the surface of some spots. In Photograph No. 8 is illustrated the smooth surface obtained when the electrode tips are kept in the proper condition, while Photograph No. 9 shows the surface of spots produced by "mushroomed" points. Not only the surface but the weld itself is affected as can be seen from Photomicrographs No. 10, 11, 12 and 13.

Photomicrograph No. 10 shows the cross section of one of the welds illustrated in Photograph No. 9. It is unetched to show what seems to be a tear in the metal, produced by the electrode tip sticking to the surface of the steel.

Photomicrograph No. 11 represents the typical structure of the sheet steel, and serves to illustrate the change which takes place in the metal after spot welding.

Photomicrograph No. 12 shows the appearance of a good spot weld. The equiaxed structure of No. 11 has disappeared and in its place there appears the coarse structure produced by the heat and the pressure. The line of the weld is visible and at both sides of it one may see the extent of the zone in which the highest temperature was reached. For the average spherical pointed electrode, this zone assumes the shape of an elongated elipse whose major axis is parallel to the surface of the steel. Photomicrograph No. 13 shows the structure at the weld of one of the spots of Photograph 9. Heat and pressure were not uniformly distributed; consequently, the recrystallized zone extends unevenly across both pieces of sheet steel. Such a structure is an indication of a poor weld, a fact which is further illustrated by physical tests. The samples illustrated above when subjected to tension gave the following results:



(Top) Photomicrograph 10. X 100
Section of Rough Spot Weld

(Bottom) Photomicrograph. X 100
Typical Structure of Sheet Steel

(Top) Photomicrograph 12. X 100
Structure of Good Weld

(Bottom) Photomicrograph 13. X 100
Structure of Poor Weld

Total Load to Break Weld		
Number	Good Welds	Poor Welds
1	1420 lb.	1265 lb.
2	1330 lb.	1130 lb.
3	1230 lb.	1125 lb.
4	1300 lb.	1190 lb.
Average	1320 lb.	1177 lb.

The requirements of electrode material are such that we are limited in our choice to non-ferrous metals and alloys. At the beginning of the development of welding in the automobile industry, forged or cold-rolled copper electrodes were used. Pure copper possesses the best electrical and thermal properties of any metal, but, in common with all other pure metals, it cannot be hardened except through cold working. As is well known, properties imparted to metals by cold working or straining disappear as the metal, through heating, passes from the strained to the unstrained condition. The operating temperatures in almost all resistance welding processes are such that copper electrodes are softened and become useless after a relatively short time. For this reason, and also because of the increased tendency toward higher working pressure, it became necessary to develop other alloys which could be satisfactorily substituted for the pure copper electrode. As a result, several alloys are now available whose electrical and thermal properties are not as high as those of pure copper but the other physical properties, especially hardness, are much better. Although their cost per pound is considerably higher, they have replaced copper electrodes almost completely because, in actual service, they are more economical due to their longer life. These alloys possess age hardening properties; that is, they can be hardened by heat treatment. However, even for these alloys there exists a temperature at which they become soft; thus, care must be taken that, in service, this temperature is never approached. In this connection, it is opportune to mention that the Ford Motor Company has very successfully pioneered in the use of cast electrodes. These cast electrodes have proved to be as good as those made from bar stock, and the casting process has resulted in a considerable saving due to the reduced amount of machining. At the present, a small plant is entirely engaged in the preparation of resistance welding electrodes.

In conclusion, I may say that welding has come to be a science instead of the haphazard art which it was not long ago. Metallurgy has played a very important rôle in its development. Further improvement will be brought about only by close cooperation of metallurgists, machine designers and users.

Flame Cutting Stainless Steel (18–8)

By FRED JUDELSOHN*

A STEEL Company, had a considerable amount of stainless steel off-analysis billets and scrap ends of plates that has accumulated due to the difficulty of cutting them up into sizes small enough to enable getting them into the furnace for remelting. They have been sawing them, but it is an expensive operation, as this material has to be annealed first and even then is very hard on the saw.

A 13-inch by 13-inch billet was cut into two pieces in five minutes, using 90 to 100 pounds oxygen pressure and about 10 pounds acetylene pressure, and size 9 tip. A No. 9 tip has an orifice of 0.161 inch diameter (20 drill size) and permits the hourly flow of 1600 cubic feet of oxygen at a pressure of 100 lb. A slab 5 inches thick, 30 inches wide, was cut into two pieces in 10 minutes, using a No. 6 tip, (35 drill size) 0.1100-inch orifice, 75 pounds oxygen pressure and about 8 pounds acetylene pressure.

The procedure is not unlike the cutting of cast iron. However, a neutral flame seemed to give the best results, the carburizing flame not working as well. The trick is in the manipulation of the torch. Where in cutting cast iron the torch is moved in semi-circles, or half-moons, along the line of cut, when cutting stainless steel the torch is moved back and forth along the line of cut, always in a straight line. See diagram.

The numbers on the torches represent the several positions of the torch in sequence of movement. The cut is started at the edge of material at 1, is moved forward in direction of cut to position 2, the distance from 1 to 2 being about $^1/_{16}$ inch. This $^1/_{16}$ inch is about the longest cut that can be made with a single forward thrust of the torch. The torch is then moved backward to position 3, this distance being anywhere from $^1/_{32}$ inch to $^3/_{64}$ inch. Then the torch is moved forward again, proceeding to position 4, cutting $^1/_{16}$-inch metal from position 2 to position 4. When moving from position 3 to position 4, the torch moves along the previous cut from position 3 to position 2 and cuts new metal from position 2 to position 4. The torch is then brought backward from 4 to 5, and the operations proceed as before.

The cutting oxygen pressure is left on all the time as the best results seem to be when the movements are made at about 60 cycles per minute, actual timing. Thus, the actual cutting action is intermittent. The cutting is much easier after some heat has gotten into the piece.

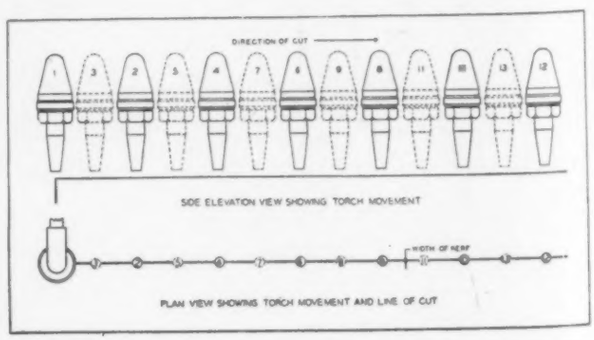

DIRECTION OF CUT
SIDE ELEVATION VIEW SHOWING TORCH MOVEMENT
WIDTH OF KERF
PLAN VIEW SHOWING TORCH MOVEMENT AND LINE OF CUT

Diagram Illustrating Cycle of Torch Movements When Cutting Stainless Steel

* Supervisor, Philadelphia District, Air Reduction Sales Company.

On the heavier thicknesses, it is advantageous to heat the front edge of the cut before starting. A flux rod is not necessary. It will be found when cutting the heavier thicknesses that there will be a drag of about 3 inches at the start of the cut, but this is soon picked up after getting into the piece a short distance. The angle of the tip to the work is exactly the same as when cutting ordinary steel. It is not inclined, and then straightened up as when cutting cast iron. The kerf is about 1/2 inch wide.

The above is only a beginning. There is no doubt that when the operator gets more experience, the tip sizes and pressures will be reduced. However, we started on the theory that lots of heat was necessary and lots of oxygen at comparatively medium pressures.

It was estimated that it would have cost at least $20 to saw-cut the 13-inch by 13-inch billet. The cost for flame cutting was about $1.10. This includes gases and labor.

Rebuilding and Facing Manganese Steel Shovel Teeth

By DON LLEWELLYN*

PHOTOGRAPHS reproduced herewith show a low-cost method of rebuilding and hard-facing manganese steel shovel teeth. The method employs old spring steel leaves for the major build-up, thus saving much time and electrode material.

Figure 1 shows worn teeth that were "half-soled" with spring steel plates and which were ready to be reconditioned again by welding and hard-facing.

Figure 2 shows a side view of two freshly built-up teeth. An old truck spring of proper width is cut to the desired length which brings the tooth out to its original dimension, after which welding rod is applied to the top of the spring leaf, bringing out the shape of the tooth. The spring leaf is welded to the manganese tooth, using stainless steel electrodes, and the end of the worn tooth is also coated with these electrodes, providing a graduated bond. The remainder of the build-up application is made with a high-carbon rod. Then the tips of the teeth are faced with a Self-Hardening rod. Figure 3 shows the completed tooth.

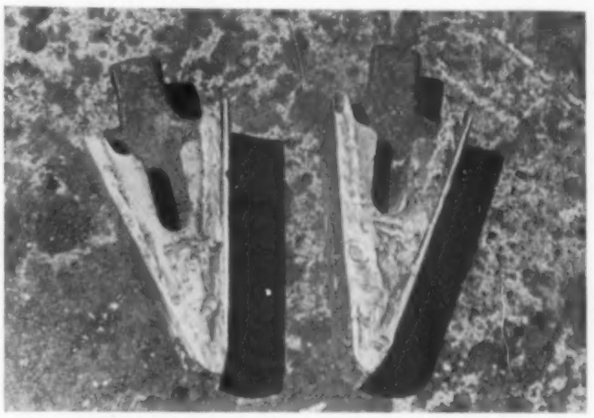


Fig. 1—Worn Manganese Steel Shovel Teeth, Showing Spring Steel "Half-Soling"

* Hard-Facing Specialist, Air Reduction Sales Co.

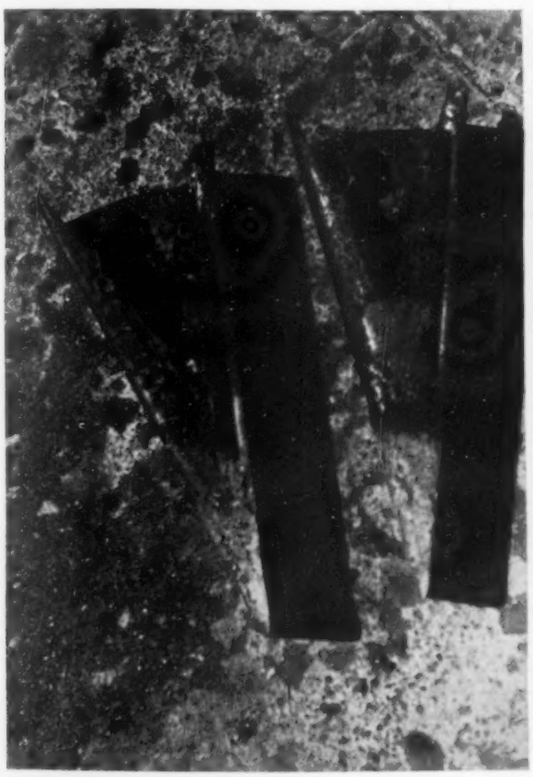


Fig. 2—Side View of Manganese Steel Shovel Teeth to Which Spring Steel Plates Are Applied

Fig. 3—Manganese Steel Shovel Teeth Reconditioned and Hard-Faced by Arc Welding

PHYSICAL PROPERTIES OF WELDS*

By G. E. CLAUSSEN†

THE physical properties of weld metal and welded joints are determined for two reasons: (1) To obtain basic design data; (2) To test the quality of the welding. Fundamentally, the two most important physical properties are density and design strength. The density of weld metal is determined on a cylindrical specific gravity specimen ($^5/_8$ in. diameter, 2 in. long) and should be within a few per cent of the density of base metal (7.80 for steel).

Tensile Test on All-Weld-Metal

The design strength is ordinarily assumed as an arbitrary fraction of either the yield strength or the tensile strength. Both values are determined from tests of all-weld-metal in the form of tensile specimens (Fig. 1). The tests are performed in the well known universal or tensile testing machine. In order to determine the yield strength, an extensometer with 2-in. gage length is fastened to the specimen. The extensometer is a form of micrometer that records the amount the specimen elongates under direct tensile stress. The readings of the extensometer plotted against the corresponding values of stress constitute a stress-strain curve (Fig. 2). Starting form O the extensions are strictly proportional to stress within the elastic limit (Hooke's Law). Beyond the elastic limit the initially straight stress-strain plot bends as shown in the diagram. The stress (tensile load divided by cross sectional area of specimen before test) at which the stress-strain plot bends away from the straight line is known as the proportional limit.

Since the proportional limit depends on the accuracy of the extensometer employed, and since the limit of usefulness of materials is usually determined by a small permissible inelastic or permanent deformation, it is standard practice at the present time to determine the yield strength rather than the proportional limit. The yield strength is determined by laying off the extension (Offset) "*m*" corresponding to the specified permissible inelastic strain on the axis of extension (Fig. 2). The intersection of line "*mn*" with the stress-strain curve is the yield strength *R*. The term yield strength should not be confused with "yield point," which is the stress *Y* (Fig. 3), at which a considerable elongation occurs without an increase in stress.

The characteristics of the stress-strain curve beyond the yield strength is shown to a contracted scale in Fig. 3. The yield point *Y-Y* is often observed in mild steel but is absent in many other materials. Beyond the yield strength the stress (calculated on the original, not on the reduced, cross section) rises to a maximum *D*, known as the tensile strength. The load which the specimen is able to support decreases after the tensile strength has been exceeded until fracture occurs at *E*.

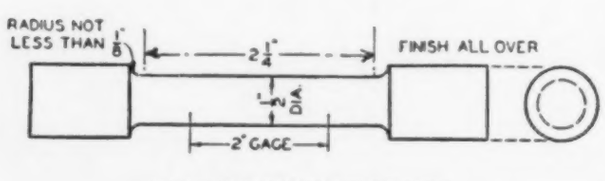


Fig. 1—All-Weld-Metal Tensile Specimen

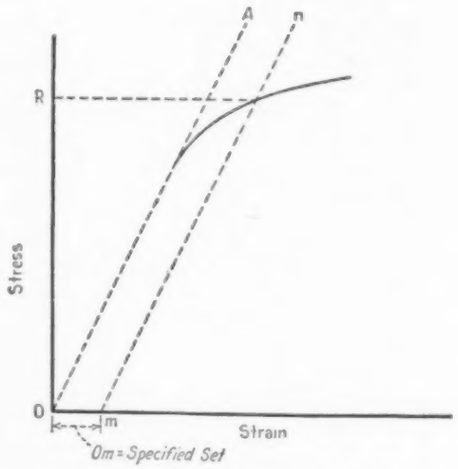


Fig. 2—Stress-Strain Curve (Initial Portion)

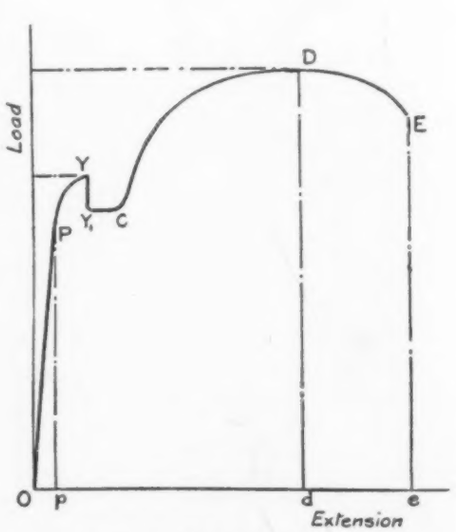


Fig. 3—Stress-Strain Curve (Complete)

Ductility

The ductility of the specimen, that is, its ability to deform under load, is determined on the fractured specimen. The two pieces of the specimen are fitted together and the distance between the gage points is measured.

* Presented as Lecture No. 4 before Lecture Course of New York Section American Welding Society, Dec. 15, 1936.

† Instructor, Polytechnic Institute of Brooklyn and Research Assistant, Welding Research Committee, Engineering Foundation.

The gage points on the specimen before test were 2 in. apart. The ratio

$$\frac{\text{Length after test} - 2}{2} \times 100$$

is known as the percentage elongation in 2 inches and is a commonly accepted indication of ductility. The difference in ductility between steel weld metal deposited by bare and shielded arc electrodes is shown in Table 1.

Table 1—Tensile Properties of Bare and Shielded Arc Electrodes

Electrode	Tensile Strength Lb/Sq. In.	Elongation % in 2 In.
Bare	40,000 to 60,000	5 to 10
Shielded Arc	65,000 to 85,000	20 to 30

Another measure of ductility is the reduction of area defined as the difference, expressed in per cent, between the original cross section and the minimum cross section after fracture, divided by the original cross sectional area. Minimum elongation and reduction of area are often specified for weld metal not because there is any definitely known relation between them and the strength of a welded structure, but because they are known by experience to be related in some obscure way to resistance against shock.

Tensile Test—Welded Joints

In addition to all-weld metal, the tensile properties of butt- or fillet-welded joints may be determined. A standard end-fillet welded specimen is shown in Fig. 4. The section of butt-welded specimens is usually reduced

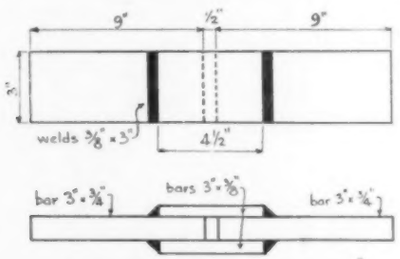


Fig. 4—End-Fillet Welded Tensile Specimen

at the weld in order to force fracture in the weld. It is customary to determine only the maximum load withstood by butt and fillet welds. The load is converted to stress for butt welds, but is usually recorded as pounds per linear inch for fillet welds.

Before other physical properties are discussed it should be emphasized that the physical properties depend on the quality of welding, which, in turn, is largely dependent upon the stage of development of the welding process for a given metal. For example, in the case of steel, the physical properties of welds in the period 1900 to about 1918 were unsatisfactory. In that period it was true, as Bournonville remarked, that welders had the heat but had not yet learned to use it. During the years up to about 1927 welding methods for steel were perfected, and sporadic reports appeared that welds made with covered electrodes had the same physical properties as base metal. Since 1927 welding has been employed in important structures on the basis that the deposited metal has physical properties equivalent to rolled steel of similar type.

Free Bend

The bend test provides information about the ductility of welded joints that cannot be obtained from tensile tests. The usual bend test is the free bend in which the face of a machined single-V butt joint is freely bent until any crack on the surface exceeding $^1/_{16}$ in. maximum dimension is developed. In some cases the weld may be bent 180° without developing cracks. Ductility is expressed as the elongation per unit length of a line perpendicular to the direction of welding drawn on the face of the weld. In preparation for the test the specimens are bent 30° at the third points in order to distribute bending uniformly over the joint. A vise may be used for specimens up to $^1/_2$ in. thick; for thicker specimens a press or tensile machine is used.

Hardness

Hardness is rather closely proportional to tensile strength, which, in turn, is to some extent related to ductility. Since the hardness test may be used on all areas of the cross section of a joint, the test indirectly shows the variation of tensile strength and ductility in the weld metal and heat affected zones. Because these variations are usually exceedingly localized no other simple test than the hardness can be used to measure them. It is often considered that an increase of over 100 Brinell numbers in a joint over the hardness of base metal is undesirable and indicative of faulty technique.

The hardness tests commonly employed are the Brinell, Rockwell, Vickers and Scleroscope. The first three tests are based on the dimensions of indentations produced by static load. In the Brinell test the diameter of the impression made by a 10 mm. steel ball under a load of 3000 kg. acting for 10 or 30 seconds is measured by means of a Brinell miscroscope. The Brinell hardness number is then determined with the aid of a chart or by dividing the load by the surface area of the indentation. In the Rockwell test the depth of indentation, rather than the diameter, is used as a measure of hardness on an arbitrary Rockwell scale. The Vickers test is similar to the Brinell but employs a diamond pyramid instead of a steel ball. An entirely different principle of hardness measurement is embodied in the Shore Scleroscope, in which the height of rebound of a diamond tipped hammer is used as a measure of hardness.

Notched-Bar Impact

A property of materials that is often important is the ability to withstand propagation of a crack. This

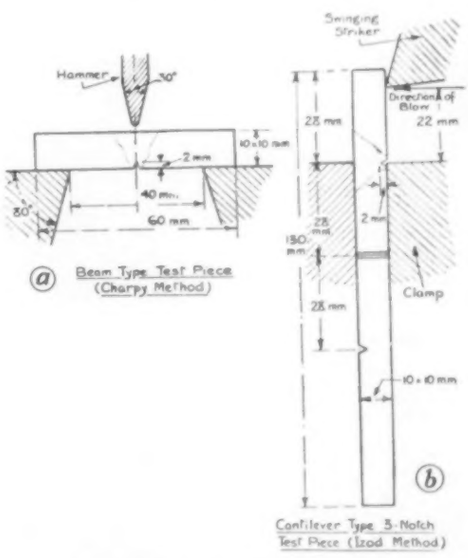


Fig. 5—Notch Impact Specimen (Izod Type)

property is measured in the notch impact test which may be used for all-weld-metal or for welded joints (Fig. 5). The Izod test shown in Fig. 5 consists of striking the rigidly gripped cantilever specimen containing a notch in the root of the joint with a rapidly moving pendulum (about 20 ft./sec.). The energy in ft.-lb. absorbed in fracturing the specimen is determined by the initial and final angles of swing and is read directly from a dial on the machine. The Charpy test also uses a pendulum to deliver the blow but the specimen is supported as a three-point beam. The pendulum strikes directly back of the notch, which is 5 mm. deep, 2 mm. diameter.

Although the notch is usually located at the root of the weld, the notch may also be located in the face or in the heat-affected zone. The sensitivity of the notch impact test in revealing brittleness and toughness in weld metal is shown in Table 2.

Table 2—Notch Impact Values of Weld Metal

Electrode	Izod Value, Ft.-Lb.
Bare	5 to 15
Shielded Arc	50 to 80

The low notch impact value of bare electrode weld metal is associated usually with its nitrogen content.

Tensile Impact

The tensile impact value of a material at different speeds of loading up to 500 ft./sec. is a measure of the ability of the material to withstand high velocity impact loads. At present, the tensile impact test as applied to welds is in a preliminary stage, but there are indications that the test will become of increasing importance in the future. The specimen consists of all-weld-metal or butt joint in the form of an unnotched tensile bar. It is struck by projections released at the desired instant from a massive rotating disk. The difference in speed of the disk before and after rupturing the specimen is a measure of the energy absorbed by the specimen. The percentage elongation and reduction of area of the fractured specimen may also be measured. In general, as the velocity of impact is increased there is no change in energy absorption or ductility until a critical velocity is exceeded beyond which ductility increases but energy absorption falls off.

Fatigue

The test commonly employed to determine the fatigue resistance of weld metal is the rotating-bend test shown diagrammatically in Fig. 6. The surface fibers of the specimen undergo a complete cycle of maximum tensile–maximum compression stress during each rotation. Other types of fatigue testing machines provide cycles of alternating (± max.) or pulsating (0 to max.) direct tension, compression, bending or torsion. The property measured in a fatigue test is the endurance limit, which is expressed in two ways: (1) The Wöhler method, which plots stress against the logarithm of the number of reversals of stress, the endurance limit being the stress at which the curve becomes horizontal. (2) The cycles method, which defines the endurance limit as the stress which a weld can withstand for an arbitrary number of reversals.

The specimens fracture in the fatigue test with scarcely any evidence of ductility. Unless the specimen is polished, fatigue failure occurs at notches or other points of stress concentration. The effect of machining away the undercut on the reversed bend fatigue limit of T

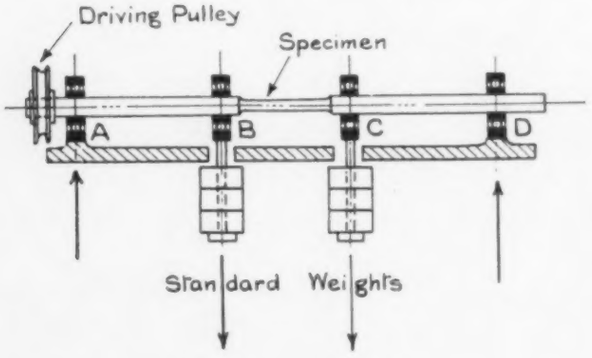


Fig. 6—Rotating-Bend Fatigue Test

Table 3—Physical Properties of Bare and Covered Electrode Welds in Mild Steel

Property	Bare Electrode	Covered Electrode
Yield Point, Lb/Sq. In.	35,000–40,000	42,000–55,000
Tensile Strength, Lb/Sq. In.	45,000–55,000	60,000–70,000
Elongation, % in 2 In.	8–15	25–35
Reduction of Area, %	15–20	45–65
Endurance Limit, Lb/Sq. In.	16,000–20,000	26,000–30,000
Impact Value, Izod Ft.-Lb.	5–15	40–50
Bend Elongation, %	20	30

Table 4—Physical Properties of Welds in Alloy Steels (Larsen)

Steel		Yield Point	Tensile St.	Elong
Carbon	Plate	25-35,000	45-55,000	45
0.20% C max.	Weld	40-45,000	50-60,000	40
Carbon	Plate	30-40,000	55-70,000	35
0.20-0.30% C	Weld	45-50,000	60-70,000	30
Nickel	Plate	40-50,000	60-70,000	45
1.0-2.0% Ni	Weld	45-55,000	60-75,000	30
Nickel	Plate	45-60,000	70-80,000	35
2.0-3.0% Ni	Weld	50-65,000	70-85,000	25
Nickel	Plate	45-60,000	80-100,000	30
3.0-3.8% Ni	Weld	65-80,000	85-100,000	20

Alloy Steel		Yield Point Lb/Sq.In	Tensile Str'h Lb/Sq.In	Elong % in 2"
Manganese	Plate	40-60,000	60-90,000	30
1.0-1.5% Mn	Weld	50-75,000	65-95,000	25
Chrome-Vanadium	Plate	55-65,000	85-95,000	30
1.0% Cr, 0.18% V	Weld	65-80,000	80-100,000	20
Stainless Iron	Plate	40-55,000	70-85,000	30
16-20% Cr	Weld	55-65,000	75-90,000	20
18-8	Plate	30-45,000	80-95,000	55
17-20% Cr, 7-10% Ni	Weld	35-50,000	70-90,000	30

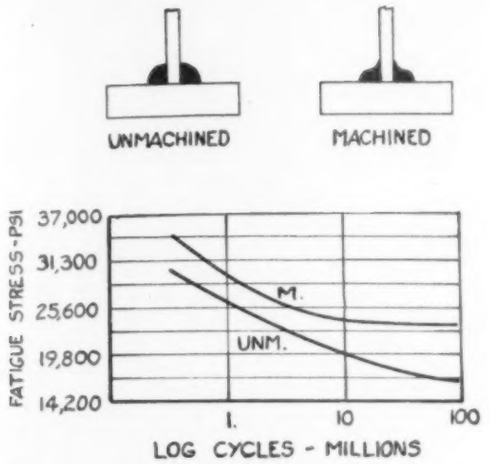


Fig. 7—Effect of Machining on the Reversed Bend Fatigue Limit of T Welds (Thum and Lipp)

welds is shown in Fig. 7 (Thum & Lipp). The removal of notches in this instance has resulted in earlier flattening of the stress-cycles flat as well as in an increase of the endurance limit. Endurance limits in rotating bending of 16,000 psi for bare electrodes and 30,000 psi for covered electrodes are common values for welds in mild steel.

Physical Properties

The physical properties of bare and covered electrode welds in mild steel are contrasted in Table 3. The low carbon content and high inclusion and nitrogen contents of bare electrode weld metal account for its inferior physical properties in all respects. Table 4 (Larsen) shows the properties that may be expected in low-alloy steel welds compared with base metal of the same composition. Table 5 provides similar information for welds in non-ferrous alloys and for bronze-welded cast iron.

Table 5—Physical Properties of Welds in Non-Ferrous Metals and of Bronze-Welded Cast Iron

Metal	Yield Strength, Lb/Sq. In.	Tensile Strength, Lb/Sq. In.	Elongation % in 2 in.	Endurance Limit, Lb/Sq In.
Aluminum (3S)	5,000	16,000	30	6,000 (500 million cycles)
Copper	10,000	30,000	30	10,000
Nickel	20,000	60,000	30	30,000
Cast Iron	...	20,000–50,000	..	
Bronze-Weld All-Weld-Metal	17,000	48,000	8–25	
Joint	40,000	46,000		

Conclusion

Test results both on the laboratory scale and on large-scale specimens, however good, can never convince us of the ultimate reliability of welded construction. For instance, riveted joints, now known to be much inferior to welds in strength and ductility on the basis of amount of material involved, are relied upon with perfect serenity justified by many years of experience. Similar service experience substantiating all the laboratory tests of the physical properties of welds has now accumulated for such welded structures as bridges, ships and pressure vessels.

Question and Answer Column

Overcoming Warping

Question.—Could you possibly give me the practical method to prevent in welded ship construction the warping of shell plating in between each frame?

Answer.—Harry W. Pierce, Supervisor of Welding, New York Shipbuilding Corp.: "Inward warping effect is a very common one in ship work. It is sometimes called 'washboarding.'

"Several years ago we used intermittent welding on all shell framing, the size of the weld being the thickness of the shell plate, with the continuity ranging from 30 to 50%. Feeling that such heavy fillets resulted in greater buckling than smaller continuous fillets, besides many other advantages of continuous welding, we now use the intermittent weld only when a $^1/_8$ in. continuous fillet is excessive in strength. Now, for example, an angle frame on a $^5/_{16}$ in. thick shell plate would have a $^1/_8$ in. continuous double fillet weld, and at web frames and bulkheads, a $^3/_{16}$ in. fillet weld. If the shell plate were $^1/_2$ in. thick, the fillets would not be greater than $^1/_4$ in. and $^5/_{16}$ in. Of course, a heavy-coated electrode with high tensile and high ductility is used.

"The reduction in size between continuous and intermittent welds is due not only to greater continuity but because the method of computing the strength of intermittent welding imposes a heavy penalty for concentration of stress at the ends of the intermittent welds. In regard to this warping, such reduction accomplishes two things—you actually use from 15 to 40% less weld metal altogether, hence less heat, and the face of the weld is greatly decreased—our theory being that shrinkage across this fillet face is part of the reason for pulling the plate inward.

"While we work progressively frame by frame from amidships, we also weld the far or 'away' side of frame first, then the side nearest amidships. It seems to reduce the sharpness of the buckle at frame line.

"I have just checked several 12 (scant $^5/_{16}$ in. thick) shell plates, at a point where there is no shape, frame spacing 2 ft., and find the inward buckle a scant $^1/_8$ in. at midpoint between almost all frames. However, now and then one around $^1/_4$ in. deep shows up, with apparently no good reason. Where there is much shape, almost none can be detected. On $^1/_2$ in. thick plates, there is very little, as well.

"Elimination of all distortion seems improbable when you realize the shrinkage which takes place along a line of welding. The periphery of a panel of shell plate, bounded by two vertical frames and two horizontal stringers, is shortened. The excess of metal in the unsupported center of panel has to do something to relieve compressive strains. So it buckles, and since the weld is all on the inside surface, it is pulled inward. Perhaps we'll someday have a non-shrinking steel and weld metal, or a cold method of welding."

WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

Alfred E. Gibson

Announcement is made of the election of Alfred E. Gibson as President of The Wellman Engineering Company, Cleveland, Ohio, succeeding Mr. George W. Burrell who becomes Chairman of the Board.

Mr. Gibson first worked for the Company during summer vacations when in College, and upon his graduation in 1909 from Ohio State University, he entered the employ of the Company in its operating department, later becoming Superintendent of its Cleveland plant, then General Superintendent in charge of both its Cleveland and Akron, Ohio plants.

In 1926 he left Wellman and became associated with the Fulton Foundry & Machine Co., Cleveland, Ohio, as Vice-President, later being elected President.

In 1928, upon the election of George W. Burrell as President of The Wellman Engineering Company, Mr. Gibson returned to the Wellman Company as its Works Manager. In 1930 he was elected Vice-President and in 1931 Vice-President and Assistant General Manager in charge of engineering and shop production, and in 1935 was appointed Executive Vice-President and now becomes its President. The Wellman Company, under Gibson's direction, has widely extended the use of the welding processes and made extensive applications of the new low-alloy, high-strength steels, to its engineered products.

Mr. Gibson is President of the WELDING SOCIETY; a member of the American Society of Mechanical Engineers; the Iron & Steel Engineers; the Society for Metals; the International Acetylene Association, and has made a reputation for himself as an authority on the development and application of low-alloy steels in welded constructions, having appeared on the programs of many societies and technical colleges the last few years.

He is a member of the Canterbury Golf Club and his hobbies are flower gardening, golf, and cabinet making. Many pieces of his cabinet work have been exhibited at the annual displays of the Cleveland Museum of Art.

Arthur E. Gaynor

It is with great pleasure that we announce the appointment of Mr. Arthur E. Gaynor as Manager of the New York Branch of the John A. Roebling's Sons Company, succeeding Mr. W. P. Bowman, deceased. "Arthur" is well known to all the members of the AMERICAN WELDING SOCIETY. He has served the Society in a number of capacities, including, Chairmanship of New York Section, Senior Vice-President for several years of the AMERICAN WELDING SOCIETY, Member of its Board of Directors and Chairman of its Membership Committee; as well as, membership on a number of standing and technical committees of the Society. Probably Mr. Gaynor is best known for his membership work during the depression. In spite of the hard times he was able by his perseverence, to secure the cooperation of a number of people in membership work, which resulted in an increase in the membership of the Society during the depression years.

We wish "Arthur" success in his new position.

Nominating Committee

With the approval of the Board of Directors, President A. E. Gibson has appointed the following individuals to serve as the 1937 Nominating Committee:

A. G. Oehler, *Chairman:* Simmons Boardman Pub. Co., 30 Church Street, New York City

E. A. Doyle (past-president), The Linde Air Products Co., 30 East 42nd Street, New York City

E. V. David, Air Reduction Sales Co., 60 East 42nd Street, New York City

Irving Hexter, Industrial Publishing Co., 812 Huron Road, Cleveland, Ohio

J. C. Hodge, The Babcock & Wilcox Co., 85 Liberty Street, New York City

E. L. Mathy, Victor Equipment Co., 844 Folsom Street, San Francisco, Calif.

H. M. Priest, Railroad Research Bureau, Frick Bldg. Annex, Pittsburgh, Pa.

Announcement of the appointment of the Nominating Committee is published in the March Journal in order to give the entire membership opportunity to offer suggestions for candidates for the offices falling vacant.

In accordance with *Art. VII, Sec. 1 (e)* the Nominating Committee is required to deliver to the Secretary in writing on or before the last Tuesday in May, the names of its nominees for the various elective offices next falling vacant with the written consent of each nominee.

Art. IV, Sec. 6 of the By-Laws provides that Nomination Ballots be mailed out to the membership by the Secretary on or before the first Tuesday in June and must be returned not later than the first day of July. The Secretary certifies to the competence and signature of all voters and then delivers the ballots to the Nominating Committee with instructions with regard to canvassing. If no nominees other than those proposed by the Nominating Committee are made by 25 qualified members, the Nominating ballots are treated as Election ballots and the results certified to the Presiding Officer at the first session of the Annual Meeting.

The offices to be filled at the coming election in October 1937 are:

President (Term 1 year) Present incumbent—A. E. Gibson, President, Wellman Engineering Company, Cleveland, Ohio—eligible to immediate re-election to the same office.

Senior Vice-President (Term 1 year) Present incumbent—E. R. Fish, Chief Engr., Boiler Div., Hartford Steam Boiler Insp. & Ins. Co., Hartford, Conn. (not eligible to immediate re-election to the same office).

Pacific Coast Divisional Vice-President (Term 2 years) Present incumbent—T. C. Smith, Designing Engr., General Petroleum Corp., Los Angeles, Calif. (not eligible to immediate re-election to the same office).

Southern Divisional Vice-President (Term 2 years) Present incumbent—E. E. Dillman, Wyatt Metal & Boiler Works, Dallas, Texas (not eligible to immediate re-election to the same office).

Directors at Large (Term 3 years) Present incumbents—A. M. Candy, Hollup Corporation, Chicago, Ill., J. H. Deppeler, Metal & Thermit Corp., New York, A. E. Gaynor, J. A. Roebling Sons Company, New York, O. E. Hovey, Consulting Engineer, New York, L. S. Moisseiff, Consulting Engineer, New York.

All of the Directors are eligible to immediate re-election to the same office.

International Congress

The British Executive Committee of the International Association for Testing Materials calls attention to the International Congress of this organization which will be held in London on April 19–24, 1937. Members of the AMERICAN WELDING SOCIETY are cordially invited to attend and any member planning to do so should communicate with the Secretary of the Society in order that they may be appointed as official representatives. Additional information may be obtained by writing to the Society headquarters.

Lincoln Gold Medal

In the January issue of THE WELDING JOURNAL there was announced the acceptance by the Board of Directors of the Society of a Gold Medal to be known as the Lincoln Gold Medal to be presented to the author of the best paper on any phase of welding published in THE WELDING JOURNAL during the year October 1936 to October 1937.

The President has appointed a Committee of three to make the Award. The Gold Medal will be presented during the Annual Convention in October 1937. The Committee of Award consists of Col. G. F. Jenks, *Chairman;* K. V. King and F. E. Rogers.

The Fundamentals of Structural Welding

A Course Offered by The Los Angeles Section, American Welding Society

The LOS ANGELES SECTION of the AMERICAN WELDING SOCIETY offers to the engineers and designers of Southern California an interesting and worth while educational course, entitled: "The Fundamentals of Structural Welding" in twelve or more evening lectures ably presented each week by a group of local specialists.

This will be a complete welding engineering course including the latest data of stress analyses, design methods, drawing details, specifications, qualification of welding operators and processes, fabrication and erection procedures, and the inspection of welded steel structures. Each student will be instructed in the manipulation of the electrode and torch, assigned to make a welded plate specimen and to make physical tests of it. Also, strain measurements will be made on a welded rigid frame for the purpose of determining residual stresses and to show the effect of welding procedure upon frame distortion. See outline of course for complete details.

This course is being offered as a membership inducement for the sum of $15.00 which includes tuition fee and an associate grade membership in the AMERICAN WELDING SOCIETY. Tuition fee to present members, associate grade and higher, is $5.00.

This membership will bring to the student twelve issues of the JOURNAL, the technical magazine of the Society; the Welding Handbook (now in preparation); and nine monthly meetings of the local Section devoted to current topics on welding.

The closing date for registration is February 20th.

TURNER C. SMITH

Chairman of AMERICAN WELDING SOCIETY Educational Committee, 2525 East 37th Street, Los Angeles, California. Phone MUtual 0171.

Outline of Course

LECTURE 1—STRUCTURAL WELDING PROCESSES, by Mr. E. J. Cipperly, Welding Specialist, General Electric Co.

Direct current, alternating current, resistance and flash welding electrical processes; bare and coated metallic electrodes; welding machines and equipment.

LECTURE 2—WELDING TECHNIQUE, by Mr. R. L. Graves, Welding Supervisor Union Oil Company of California, Mr. J. C. Gowing, of J. C. Gowing Company, Mr. J. J. Bruton, Linde Air Products Company.

Explanation and demonstrations of; Current, voltage, polarity, arc stability, magnetic effects, arc temperatures, types of joints, types of welds, manipulation of the electrode.

Gas cutting—adjustment of flame and handling of torch.

Gas welding—types of flames, torch tips, manipulation of flame.

LECTURE 3—WELDING PROCEDURE, by Mr. R. L. Graves, Mr. J. C. Gowing, Mr. J. J. Bruton and others.

Procedure in making various structural welds. Tables of various arc welds, giving required amounts of power, electrode and time. Student's shop practice in making welds.

LECTURE 4—INSPECTION AND TESTING OF WELDS, by Mr. D. S. Roberts, Testing Engineer, Smith-Emery Company, Mr. Tabor DeForest, Testing Engineer, Magnaflux Corporation.

Methods of testing welds, i.e., tension, nick-break, bend, density, fatigue, deep etch, corrosion. Magnetic tests. Exographs. Interpretation of results obtained. Typical inspection reports. Strain measurements of a welded rigid frame.

LECTURE 5—QUALIFICATION TESTS OF WELDING OPERATORS, by Mr. W. A. Howard, Inspection Supervisor, General Petroleum Corporation of California, and Mr. R. L. Graves.

Explanation of qualification requirements of various codes.

Common faults in welds—where to look for trouble—methods of correcting faulty workmanship.

Physical tests on weld specimens made by students.

LECTURE 6—METALLURGY OF WELDS, by Dr. D. S. Clark, Department of Physical Metallurgy, California Institute of Technology.

Fundamentals of metallurgy significant to welding—the nature of metals and alloys—the nature of steel—the melting of steel as applied to welding—the mechanism of solidification—the metallographic structure of welds—metallurgical factors which influence the property of welds.

LECTURE 7—PHYSICAL PROPERTIES OF WELDS, by Mr. P. D. McElfish, Materials Engineer, Standard Oil Company of California.

Tension, compression and shear values by static tests. Fatigue values by rotating beam and alternating tension and compression tests. Effect of profile on cyclic loadings. Effect of temperature and corrosion on welds.

LECTURE 8—STRESS ANALYSIS OF VARIOUS WELDED JOINTS, by Mr. L. T. Evans, Bridge Design Engineer, U. S. Army Engineers Office.

Stress analysis of butt, end fillet and side fillet welds. Stress analysis of various structural connections, i.e., beam clips, shelf angles, continuity splices, brackets, etc. Stress concentration factors for shape of welds and joints.

LECTURE 9—NOMENCLATURE FOR STRUCTURAL WELDS, by Mr. R. W. Binder, Engineer, Bethlehem Steel Company.

Nomenclature and its application to detail drawings.

LECTURE 10—DESIGN OF STRUCTURAL MEMBERS, by Mr. H. C. Whittlesey, Consulting Structural Engineer.

Design of various welded members, i.e., girders, trusses, rigid frames, etc.

LECTURE 11—RÉSUMÉ OF LECTURES 9 and 10, by Messrs. Binder, Evans and Whittlesey.

LECTURE 12—STRUCTURAL WELDING SPECIFICATIONS, by Mr. R. W. Binder.

SECTION ACTIVITIES

CHICAGO

The regular monthly meeting of the Chicago Section was held on February 19th. The subject of the meeting "Factors Affecting the Properties of Welds and the Base Metal Adjacent to the Weld" was discussed by Leon C. Bibber, Welding Engineer, U. S. Steel Corp., and R. E. Long, Research Engineer, Hollup Corporation. In addition to this, Mr. Bibber discussed the important work being done by the Society on Nomenclature, Definitions and Symbols. A motion picture "Stepping Stones of the Pacific" was shown, preceding the regular meeting.

The March 19th meeting will be held in the Medical and Dental Arts Building, 185 N. Wabash Ave., in the Spanish Room on the 23rd Floor, with a dinner at 6:30 and the meeting at 7:45.

Mr. Sheffli, of the American Steel Foundries, will talk on "The Use of Castings in Assemblies of Heavy Welded Sections." Jack Gordon, of the Fabricating Division of the Taylor-Winfield Corporation, will speak on the design and fabrication of large welded assemblies and will show a motion picture based on some of the interesting jobs done by his firm.

CLEVELAND

The fourth regular meeting of the Cleveland Section was held on March 10th. Mr. Harold O. Jones, Supervisor of Applied Engineering Dept., Air Reduction Sales Company, presented a paper on "Flame Hardening;" and Mr. Albert Williams, Supervisor of Welding Department, Wellman Engineering Company, presented a paper on "Flame Cutting in the Heavy Construction Industries."

DETROIT

The next meeting of the Detroit Section will be held on March 26th. Mr. T. C. Fockler of the Westinghouse Electric and Manufacturing Company, will speak on "Welded Machine Designs." It is expected that the paper will be of immediate practical value to the machine tool industry. An invitation to attend has been extended to the members of the American Society of Tool Engineers.

The Detroit Section of the Society has been elected a member of the Affiliate Council of the Engineering Society of Detroit. The Section's representatives on the Council are W. M. Hayes and D. H. Corey.

LOS ANGELES

The regular meeting of the Los Angeles Section was held February 18th at the Los Angeles Chamber of Commerce Building with 85 members and guests present. The meeting was preceded by a dinner at 6:30.

The first speaker, Mr. B. J. Brugge, recently Welding Engineer for the Anglo-Persian Oil Co. of Abadan, Persia and at present Sales Engineer for The Lincoln Electric Co., analysed the material presented in the February issue of THE WELDING JOURNAL.

The second speaker, Mr. Arthur Beggs, Western Sales Manager of the American Airlines, Inc., gave an interesting talk on "Modern Air Transportation" and took his listeners on an imaginary trip to New York on one of the new sleeper planes.

The third speaker, Mr. Kenneth Anderson, Pacific Coast Representative of Steel and Tubes, Inc., spoke on "The Manufacture of Welded Tubes and Pipe by the Continuous Electrical Resistance Process." His talk was illustrated by motion pictures showing manufacturing processes. Numerous specimens of tubing and tubing tests were presented for inspection.

The fourth speaker was Mr. Charles Babbitt, Welding Foreman, Western Pipe and Steel Co., who showed and described a motion picture of the welding arc.

MARYLAND

On Friday evening, February 19th, the Maryland Section had the pleasure of having Mr. J. F. Lincoln of The Lincoln Electric Company, as its speaker. The meeting was the largest held at the Engineers' Club in the past five years with an attendance of two hundred and twenty five. Mr. Lincoln spoke on "Welding *vs.* Prejudice."

On February 24th at the Engineers' Club, Dr. Rudolph Bernhard of the Baldwin-Southwark Corporation, showed a movie reel on "Bridge Survey on the German State R.R.," followed by an explanatory talk by Dr. Bernhard.

MILWAUKEE

A technical meeting of the Milwaukee Section was held on Friday, February 26th., at the City Club of Milwaukee. Mr. J. C. Joublanc, Chief Metallurgist, Harnischfeger Corp. presented an address on "Some Metallurgical Aspects of Arc Welding." In addition to the subject matter, Mr. Joublanc discussed the effects of stress-relieving and normalizing on welded structures.

MONTANA

At a meeting on January 6th of the Montana Section, Mr. Wm. M. Galloway of the U. S. Engineers presented a historical paper on "Welding on the Fort Peck Dam Project." Following the presentation of Mr. Galloway's paper, an open discussion was held of an article on Thermit Welding appearing in the December issue of THE WELDING JOURNAL. A paper by V. H. Byrnes, Welding Supervisor, was postponed until the February meeting due to Mr. Byrnes absence.

At the February 3rd meeting Mr. Byrnes paper was again postponed due to his not being available.

A Nominating Committee consisting of C. W. Capper, Chairman; Donald Liggett, Harry S. Griffith, Roy L. Spaulding and James F. Wedgeworth, was appointed at this meeting. A round table discussion was held on Welding Procedures. Some very interesting questions about local problems were asked and answered by those present. Considerable time was devoted to a discussion of Corrosion of Welds.

NEW YORK

The regular monthly meeting of the New York Section was held on March 2nd. Mr. George A. Jessop, Chief Engineer of the S. Morgan Smith Company, presented a paper on "Welded Structures for Hydraulic Turbines." Some very large welded structures for the Bonneville Project on the Columbia River recently fabricated by Mr. Jessop's company were covered in his presentation. Some of the fabricated units are the largest of their type ever built in the United States and include turbines which are larger than have ever been produced anywhere.

The coming meetings of the New York Section are:

April 13—Shipbuilding

April 19—Joint Meeting with A.S.M. Stresses in Welds and Their Elimination.

May 11—Annual Business Meeting—Motion Pictures Showing New Developments in Welding.

PHILADELPHIA

An excellent meeting of the Philadelphia Section was held on Monday, February 15th. Mr. F. G. Flocke, Technical Service Engineer of the International Nickel Company, gave a very interesting talk on "The Electric Welding of Monel Nickel and Nickel Clad Steel."

PITTSBURGH

One of the most successful and largest attended meetings held this year was on February 17th in the Blue Room of the Roosevelt Hotel, Pittsburgh. Mr. J. D. Gordon, Manager of the Taylor-Winfield Corporation, delivered an illustrated talk on "Why Use Fabricated Steel." Mr. Gordon's talk was received with tremendous interest and it was the opinion of those present that it was one of the best welding meetings the Section has had for a long time. Following the talk and showing of pictures an open discussion was held lasting almost an hour.

Considerable more interest is being aroused in the welding field due to the upturn in business and a general use of welding in all industries and it is no doubt likely that meetings in the future will be well attended.

Prefacing the talk by Mr. Gordon, Mr. W. W. Reddie, Representative on the Board of Directors, gave a short talk emphasizing the advantages to be gained by membership in the various sections and encouraged those present to consider carefully the possibility of being members of the Pittsburgh Section.

The next regular meeting of the Pittsburgh Section will be held Wednesday night, March 17th in the Roosevelt Hotel. Mr. G. O. Carter, Consulting Engineer, The Linde Air Products Company, will address the Section on "Past and Future of Welding in the Pittsburgh District."

SAN FRANCISCO

The February meeting of the San Francisco Section was held at the Engineers' Club on the 26th. Dinner preceded the meeting. The Chairman of the Membership Committee read a report on the membership activities of the Section. Mr. Brooker, an Engineer of the Standard Oil Company of California, substituting for Mr. K. V. King, reviewed several outstanding articles in the last issue of the Journal.

The speaker of the evening, Mr. Harold Bell, Service Operator of The Linde Process Service Department, presented a paper on "Oxyacetylene Cutting and Manufacture and Utilization of Rolled Steel," which was illustrated with lantern slides. Following this, two reels of movies on flame cutting were shown through The Linde Air Products Company.

EMPLOYMENT SERVICE BULLETIN

POSITIONS VACANT

V-76. Welding Shop Foreman. Experienced in fabrication of annealed and X-rayed A. P. I.-A. S. M. E. Code Vessels. State age, nationality, outline of education and experience, picture and salary expected. Location Middle West.

V-77. Would like to employ a Welding Engineer of some years experience who would be qualified to lay out the welding procedure on plates and structural work so as to minimize shrinkage distortion, to design the proper types of welded joints, and to supervise field welding operations including qualification of welders and sufficient inspection to insure welds of good quality.

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BOOKS

Resistance Welding Electrodes. A new catalog has been issued by the Electroloy Company, Inc., 50 Church Street, New York. This catalog includes the physical properties, recommendations and specifications of various alloys for all types of resistance welding equipment, including spot, seam, projection, flash and butt welding.

A new booklet No. DH-984 covering Page Hi-Tensile F Electrodes has just been issued. This booklet describes this shielded arc electrode in detail and the shielded arc method of welding, with illustrations showing the procedure for various types of welds. A copy of this booklet will be sent by the Page Steel and Wire Division of American Chain & Cable Company, Inc., Monessen, Pa., on request.

"The Alloys of Iron and Carbon," Vol. II—Properties, by Frank T. Sisco. Published for The Engineering Foundation by the McGraw-Hill Book Co. Inc., New York, N. Y. Price $8.00. This volume is the final portion of a correlation of data and a critical summary of the world's knowledge on the constitution and properties of iron-carbon alloys. The chapters cover: Introduction; Variables Affecting the Properties of Cast Steels; Mechanical Properties of Cast Steels; Mechanical Properties of Hot-Worked Carbon Steels; Mechanical Properties of Cold-Worked Carbon Steels; Mechanical Properties of Heat-Treated Carbon Steels; Effect of Cross Section and Other Variables on Mechanical Properties; Manufacture and Special Properties of Gray and White Cast Iron; The Mechanical Properties of Cast Iron; Malleable Cast Iron; Behavior of Iron-Carbon Alloys under Repeated Stress; Effect of Temperature on Properties: I. Short-Time Tests; Effect of Temperature on Properties: II. Creep Tests; The Corrosion of Commercial Iron-Carbon Alloys; Miscellaneous Physical Properties of Iron-Carbon Alloys; Electric and Magnetic Properties of Commercial Iron-Carbon Alloys; Miscellaneous Engineering Properties of Commercial Iron-Carbon Alloys, and a Bibliography.

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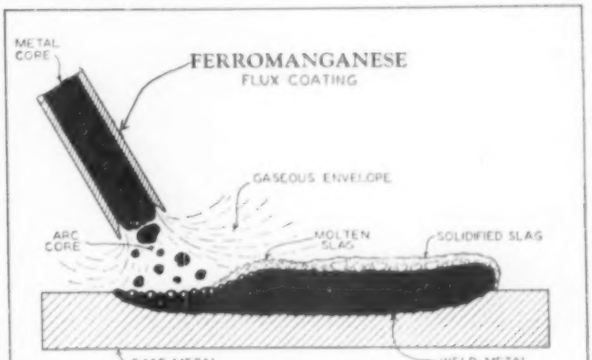

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